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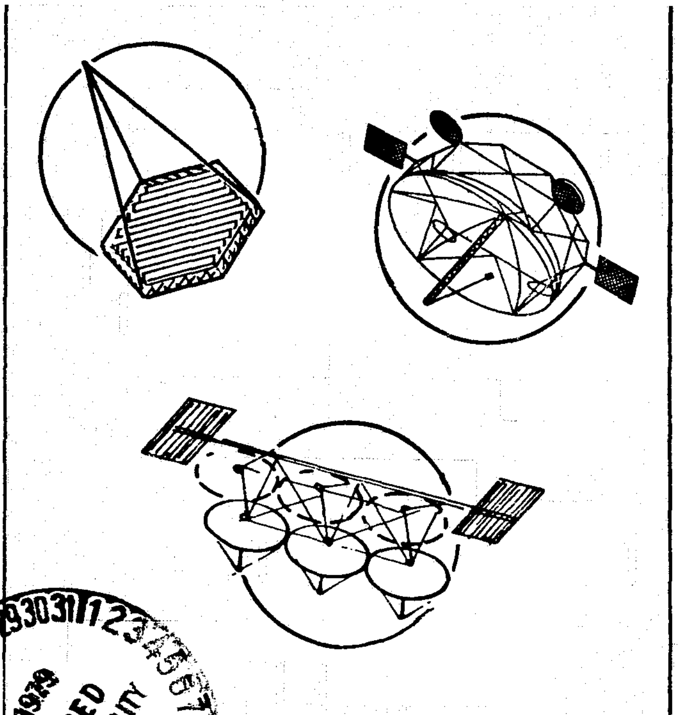
# ADVANCED TECHNOLOGY REQUIREMENTS FOR LARGE SPACE STRUCTURES

## PART 5 FINAL REPORT

## ATLASS PROGRAM REQUIREMENTS



By

E. Katz, A. N. Lillenas, and J. A. Boddy

September 1977

Prepared under Contract NAS1-14116, MOD 6

by ROCKWELL INTERNATIONAL, SPACE DIVISION

for NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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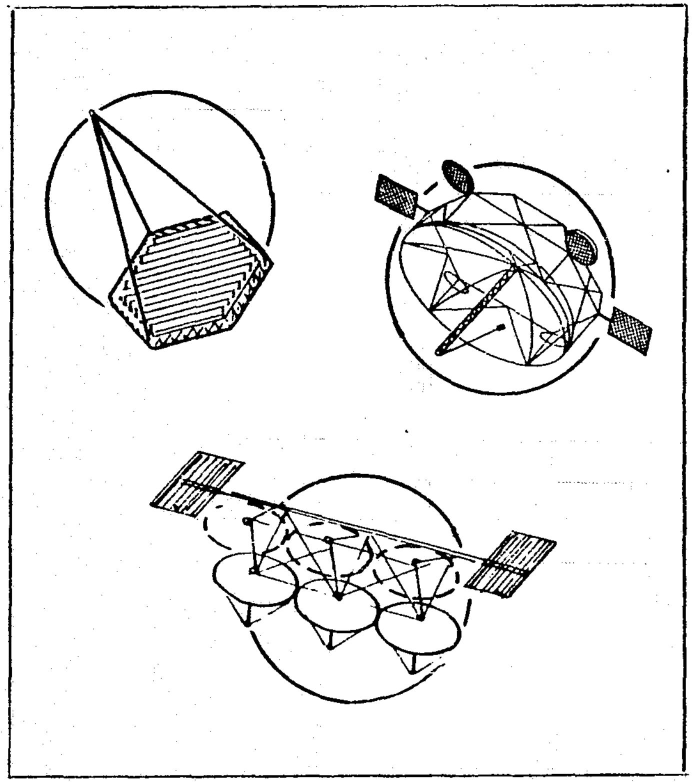

# ADVANCED TECHNOLOGY REQUIREMENTS

# FOR

# LARGE SPACE STRUCTURES

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## FOREWORD

The Space Division of Rockwell International has been conducting a Special Emphasis Study of Large Space Structures as a part of the overall Advanced Technology Laboratory (ATL) program for the Langley Research Center of the National Aeronautics and Space Administration. The work has been performed under Contract NAS1-14116, Mod. 6; Dr. E. T. Kruszewski was the Contracting Officer's representative and Mr. E. C. Naumann the technical monitor.

This report documents the results of a Part 5 of the above described Special Study. Part 5 is the final submittal of the study and has the objective of identifying and prioritizing technology requirements for a particular scenario of future large area space systems. The study was designed to be of assistance in helping define general objectives of the newly formulated ATLASS Planning Office.

The study was conducted under the direction of E. Katz, Rockwell's manager for Large Space Structures programs. A. N. Lillenas was the principal investigator, assisted by J. A. Boddy, for the Part 5 activity. Other contributors are credited on page 37 of the report.

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# INTRODUCTION

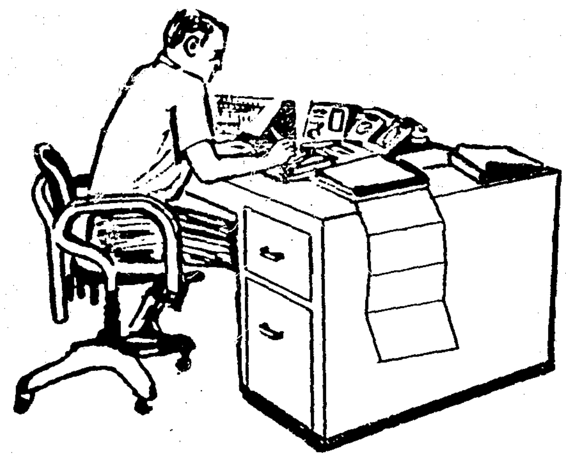
This report, prepared by the Space Division of Rockwell International, presents the results of the final special task assigned under Contract NAS1-14116. Study results identify special technology areas which may require special development emphasis in order to accomplish an assumed scenario of future space systems requiring large area space structures. Previous work under this contract has identified large area erectable configurations, structural "building block" elements, requirements for ground and flight experiments, and concepts for the installation of mission and subsystem equipment.

# OBJECTIVES

The specific objective of this large area space systems activity was to identify and prioritize those technology developments which would be required to support a particular scenario of future space systems. This specific objective is a part of the general objective of the ATLASS (Advanced Technology for Large Area Space Systems) Planning Office: i.e., to define an ATLASS program which would provide a technology base for the development of future large area space systems.

# OBJECTIVES

GENERAL: DEFINE AN ATLASS PROGRAM.
TO SUPPORT THE LARGE AREA
SPACE SYSTEM OPTIONS OF THE 80'S



SPECIFIC: IDENTIFY AND PRIORITIZE THOSE TECHNOLOGY
DEVELOPMENTS REQUIRED TO SUPPORT
A SPECIFIED MISSION SCENARIO

# OUTLINE

- MISSION SCENARIO
- TECHNOLOGY REQUIREMENTS
- TECHNOLOGY ASSESSMENTS
- CONCLUSIONS

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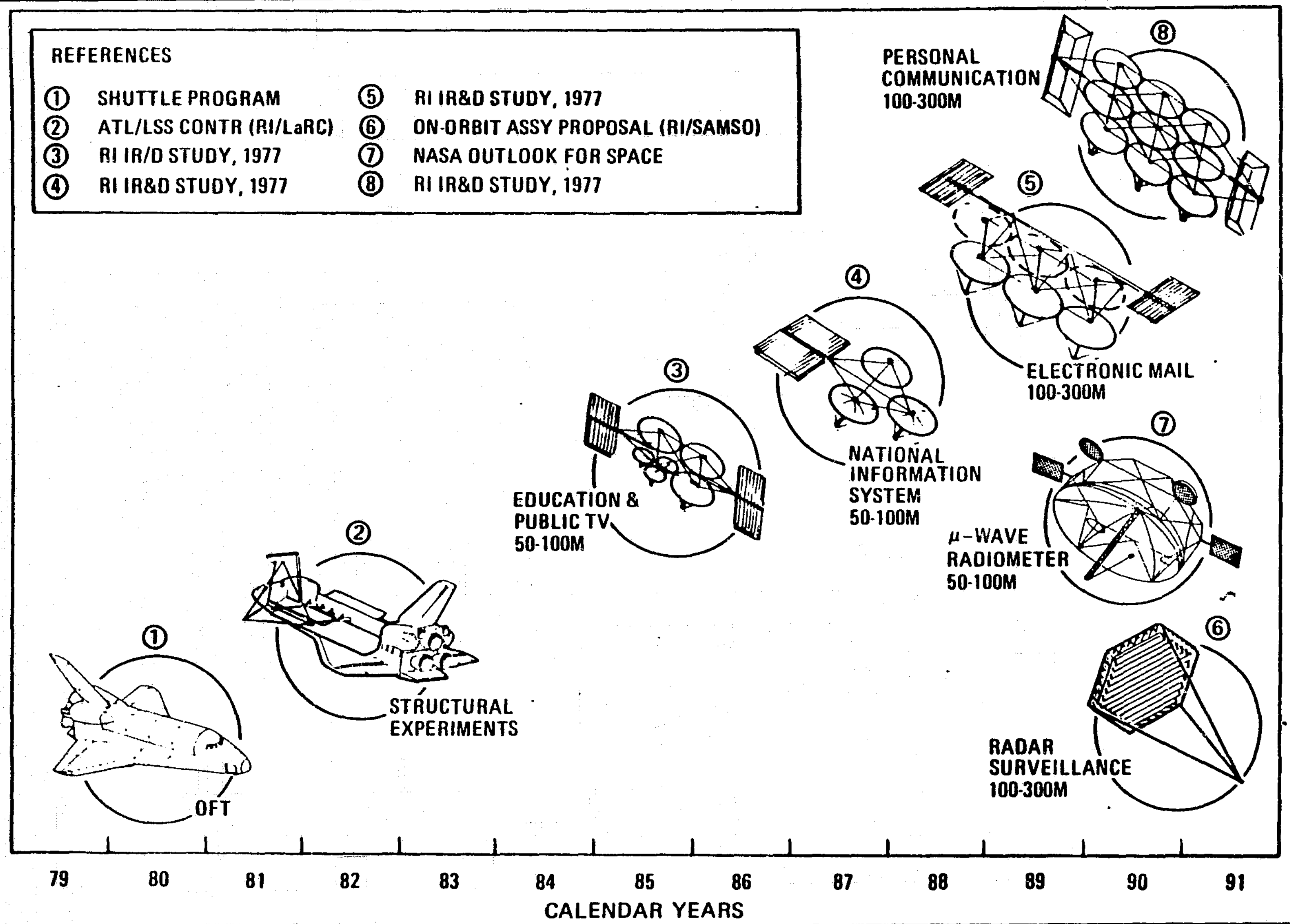
# PROSPECTIVE MISSION SCENARIO

Eight potential space missions of the 1979 to 1991 time period are shown as representative activities related to the large area space systems of the future. The first two items indicate Shuttle orbital flight tests (OFT) and structural experiment flights which will be precursors to the implementation of the large space structure systems. In compliance with NASA guidelines for this study, the scenario includes those missions which were previously identified in "Scenario A" of Rockwell briefing, PD77-20, June 1977. In addition, the radar surveillance mission (Item 6) has been included because of the growing interest in this concept as evidenced by the pending Air Force/SAMSO study program on the subject. Appendix A provides further details of the eight mission concepts shown. Three main missions selected as being representative of the opposite scenario are described further in following charts.

# PROSPECTIVE MISSION SCENARIO



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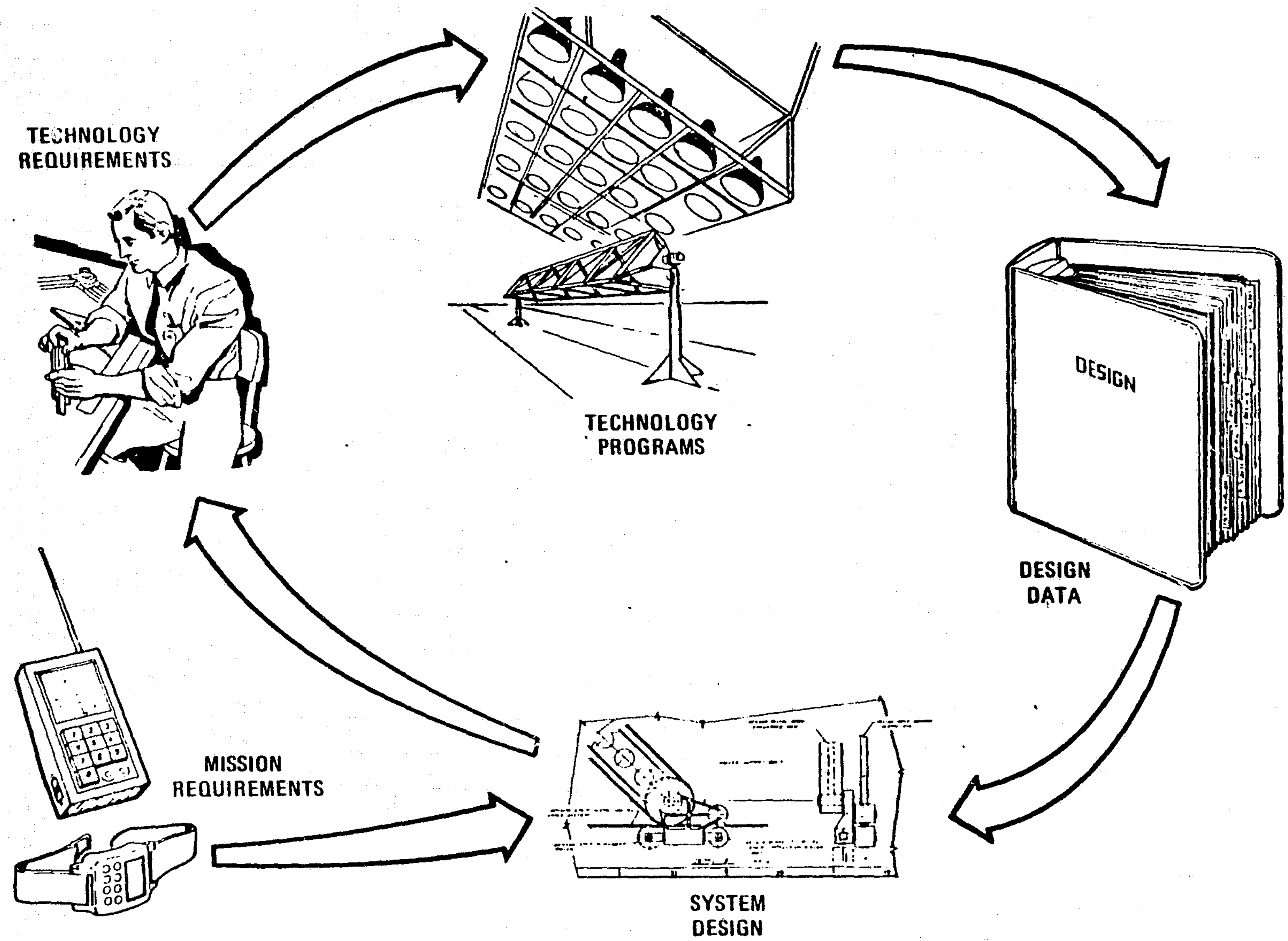
# TECHNOLOGY AND SYSTEMS

The subject of technology requirements for space applications is intimately related to the missions to be accomplished. However, the systems designers for the required spacecraft and systems operations are dependent on the technology available in each area in meeting the mission requirements. Thus, technology requirements must be anticipated and technology development programs must be planned and funded in order to provide the accurate design data for the systems procurement.

We do not presently have firm requirements for specific future large area space systems. The present study attacks the problem of "starting someplace" by proposing a set of "strawman" missions, determining a more firm set of space system requirements for these missions, and then estimating the technology advances required in order to have the design data required by a future need date. This approach is believed to accomplish a first step in an orderly preparation for future needs.

# TECHNOLOGY & SYSTEMS



## NATURE OF THE SYSTEMS DESIGN PROBLEM

As noted in the preceding discussion, it is necessary to "start someplace" in the formulation of the technology requirements. In this study we have started with the assumption of a particular set of missions. While this is a necessary step, it is not sufficient -- we must also consider the physical and functional characteristics of space systems which could accomplish these missions. The problem highlighted on this chart is that there is a wide range of possible design solutions, any one or combinations of which may prevail. For example, one of the concepts shown on the previous chart was that of a large-size radiometer for scanning of earth surface and atmospheric phenomena. The NASA Outlook for Space study suggests the eventual need for microwave radiometer antennas as large as 400 meters in diameter. Smaller sizes also are useful and more appropriate for earlier missions.

The opposite chart illustrates various approaches that may be used in providing the large area space structure for a radiometer antenna. Whatever is the final approach influences the technology that must be developed. The Grumman concept illustrated represents a 100-meter-diameter antenna for operation in the 2.5 GHz frequency range. The structural assembly concept proposed is a combination of a deployable 50-meter central mast canister onto which is attached on-orbit fabricated (beam machine) radial and circumferential members. An orbital construction base facility is proposed for the concept fabrication and assembly operations. The antenna mesh would be installed on the structure with EVA assistance.

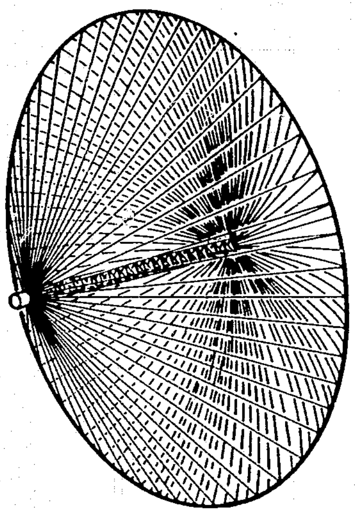
The Rockwell concept illustrated represents a possible 50-meter-diameter spherical microwave reflector in combination with four small radar antennas to provide a passive/active sensor set for coordinated observation of earth surface and atmospheric variables to assist in long-term weather prediction. The planned structural support for this large antenna concept is that of on-orbit assembly of a matrix structure of struts and unions. The Orbiter, equipped with construction aids, would be the construction base for this concept.

The MDAC concept represents a fully deployable radiometer which would be brought to the operational orbit by the Orbiter and then automatically deployed to its operational configuration. Antenna diameters greater than approximately 30 meters will require added articulation of the radial ribs in order to be packaged in the Orbiter cargo bay. All large mesh-covered antennas will probably require on-orbit adjustment to obtain shape accuracies necessary for high-frequency operations.

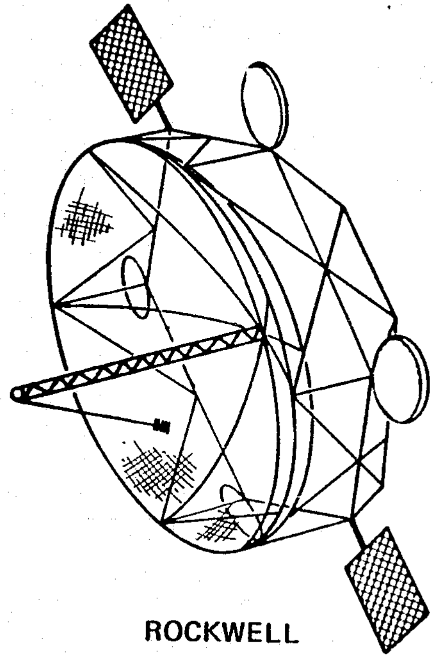
The approach taken in this study is to select those system design concepts which would use technology common to other missions and which would not be highly sensitive to variations in mission parameters. In this context, the Rockwell concept was selected for the radiometer mission.

# NATURE OF THE SYSTEMS DESIGN PROBLEM

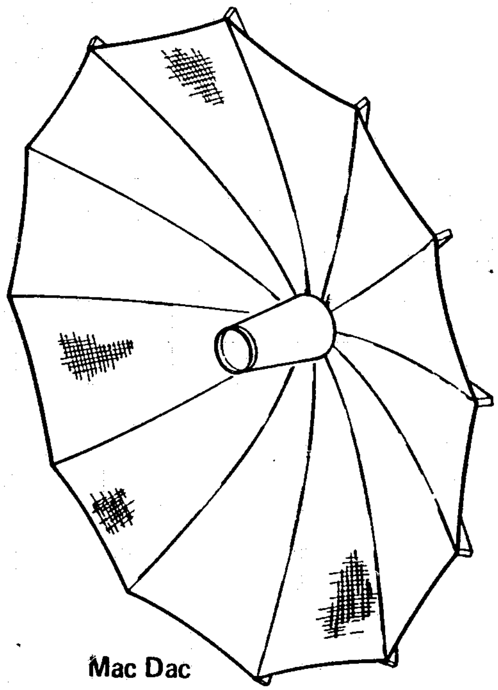
EXAMPLE: $\mu$ - WAVE RADIOMETER



GRUMMAN



ROCKWELL



Mac Dac

- SIZE
- PASSIVE/PASSIVE-ACTIVE
- ORBIT
- FREQUENCY
- RESOLUTION
- REPETITION CYCLE

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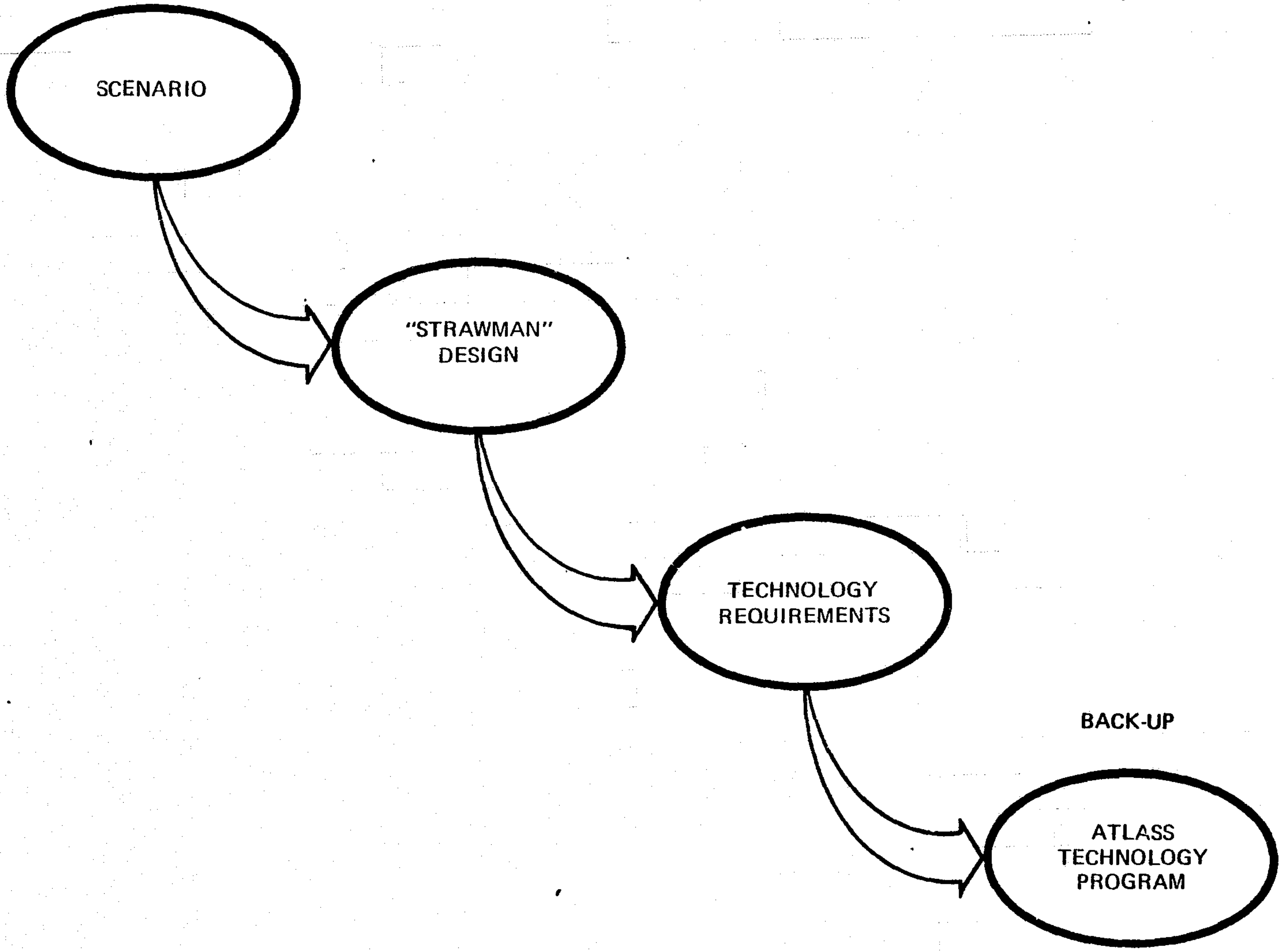
## METHOD - CHART 1

The opposite chart summarizes the methodology used to establish the technology requirements. The candidate scenario was reviewed and analyzed, and from this study three "strawman" design concepts were selected as representative of potential future missions requiring relatively large area structures. System requirements for the missions then were developed to the level that would allow estimation of the various space technology requirements necessary to support each of the "strawman" satellite design, implementation, and operations concepts. The identified requirements were then consolidated into a list of representative technology areas which require further attention in supporting the future needs of the space program.

Study backup materials relating the technology development requirements determined during the study with the current ATLASS technology program plans are included in Appendices A, B, and C.

# METHOD - CHART 1



## TIMELINING THE TECHNOLOGY NEED DATE

The need date for the various technology levels for a given space program is related to the program start decision, the development lead time for the satellite system, and the inital operational capability (IOC). The chart shows a simplified mathematical model of these relationships. The actual needs cannot be considered until a relatively firm commitment for a given space program is established. Each major system requires a "development lead time" in order to put together all the subsystems and mission operations plans into an integrated system. The various technologies required for support of the mission are largely required prior to the start of this development cycle.

The technology need date could occur immediately after program go-ahead for some technologies, depending on the other requirements as worked backward from the IOC. Other technology need dates could be delayed until later in the development cycle, depending on their interrelationship with the total system design and their interfacing subsystems. A following chart indicates that for the communications systems the earliest technology requirements would be for (1) modeling and scaling laws (1979), and (2) ground test and validation facilities (1980). These technology areas represented ones requiring a significant degree of advancement in order to accomplish first applications of a new on-orbit assembly of a large space structure platform. In this illustration, the 1985 need dates indicated would apply to the later scheduled satellites of the communications series.

# TIMELINING THE TECHNOLOGY NEED DATE

$$\left[\text{PROGRAM START}\right] \leq \text{NEED DATE} \leq \left[\text{(OPERATIONAL DATE)} - \text{(DEVELOPMENT LEAD TIME)}\right]$$

# TECHNOLOGY REQUIREMENTS - COMMUNICATIONS

Four of the "Scenario A" mission concepts (rererence Rockwell Briefing: PD 77-20) were communications-type satellites. These, together with their proposed operational time periods, were as follows:

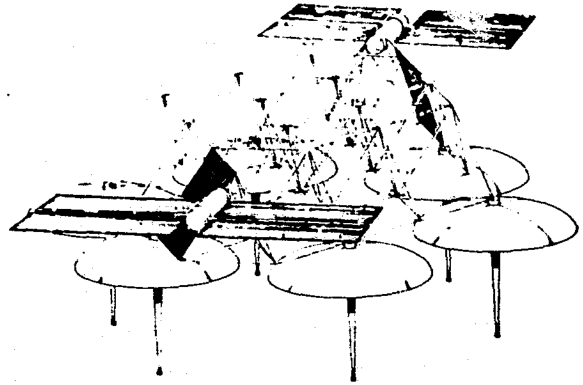
- Education and Public TV (1985)
- National Information System (1987)
- Electronic Mail (1990)
- Personal Communication (1993)

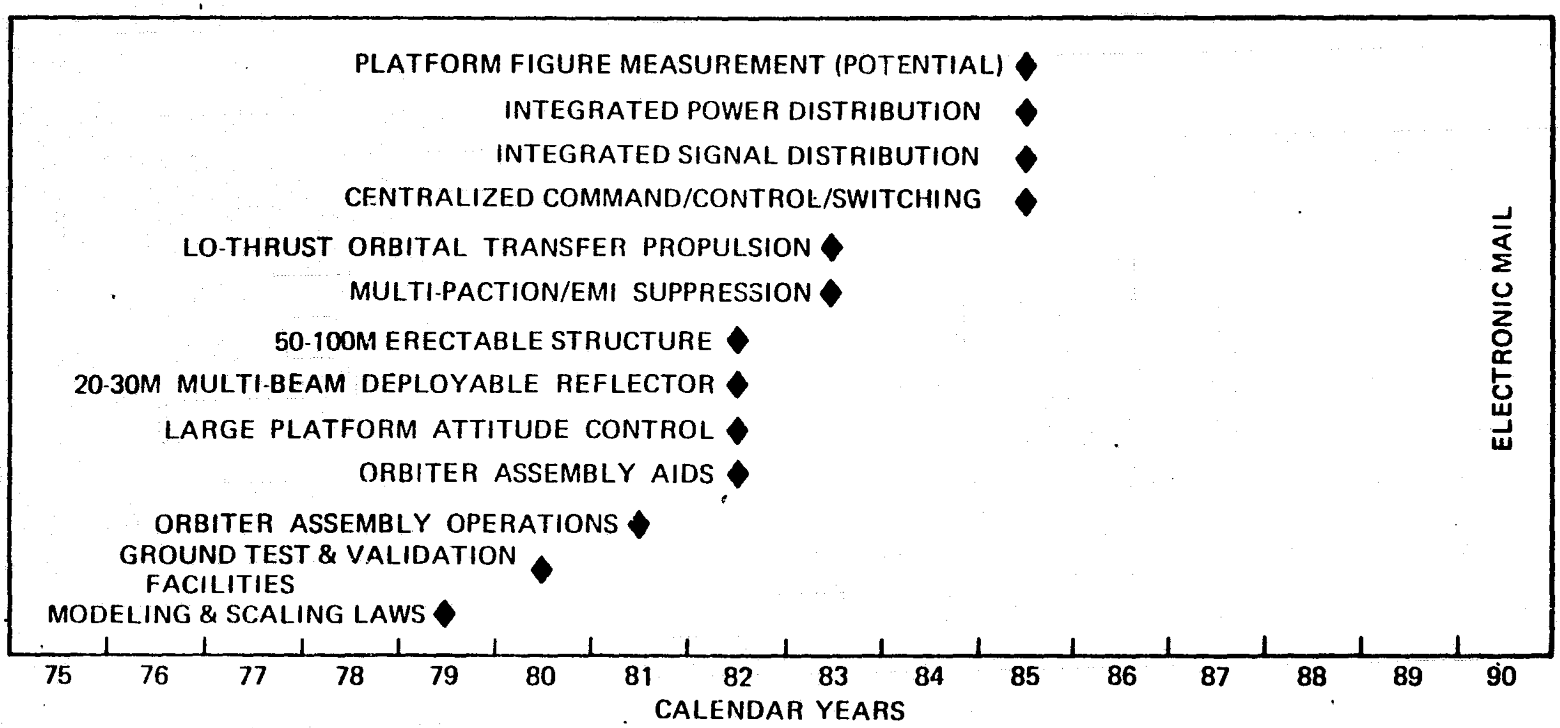
The Electronic Mail concept shown on the opposite sketch was selected as representative of this mission group; its estimated system and mission characteristics are listed in the upper left. The six 23-meter deployable antennas with 169 beams per reflector will provide service to 845 major postal centers and cover better than 65 percent of the continental USA area. Nineteen different frequency band requirements are estimated to prevent transmission interference.

The lower box of the chart summarizes 13 technology requirement topics identified as important areas in which further development may be required in order to accomplish the "communications group" of missions. Subsequent charts will more completely define what is meant by these technology items. Also indicated are the "need" dates for each of the requirements. These need dates are essentially when firm technology data are available for use of engineers to start designing the spacecraft and mission operations (also, see next chart).

# TECHNOLOGY REQUIREMENTS - COMMUNICATIONS

- ELECTRONIC MAIL CONCEPT
  - OPERATIONAL 1990, GEO
  - TETRAHEDRAL ERECTABLE PLATFORM
  - 6-23M ANTENNAS (DEPLOYABLE)
  - 1014 DATA CHANNELS
  - 60 KW POWER REQMT
  - 860M$^2$ SOLAR ARRAY
  - MASS ON ORBIT:
    - 17,800 KG (DRY)
    - 24,800 KG (WITH RCS FUEL)





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## TECHNOLOGY REQUIREMENTS - RADIOMETER

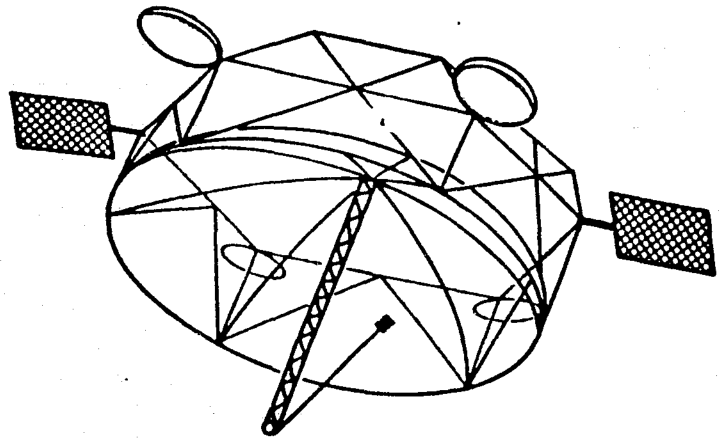
The "Scenario A" source (Rockwell PD 77-20) suggested the future need for two large radiometer instruments for long-term weather forecast technique development and implementation. Sizes of 50-meter and 100-meter diameters were suggested. The Rockwell concept, utilizing a combination of active and passive measurements, was shown on an earlier chart discussing the nature of the systems design problem. This was selected as a representative mission application area. The sketch is repeated on the opposite chart.

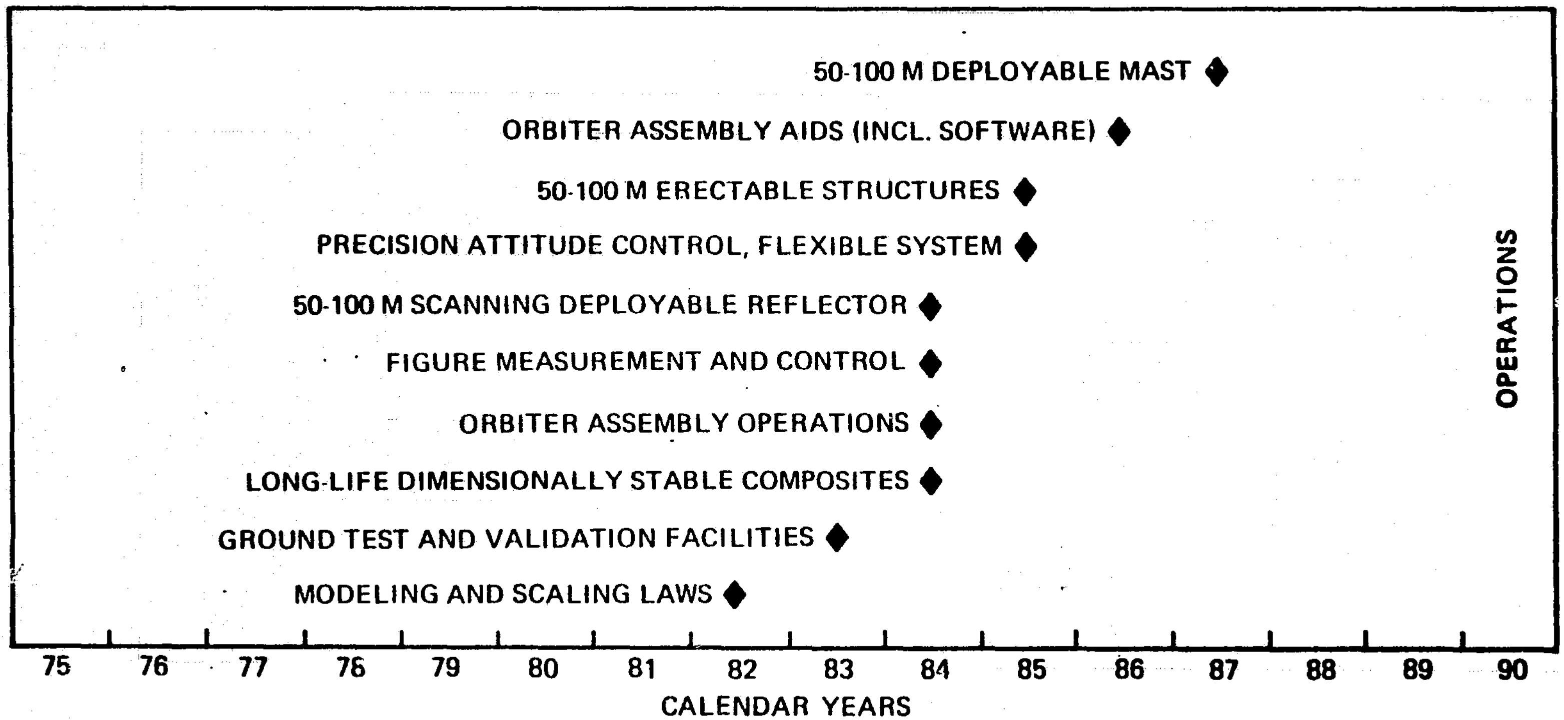
The pertinent systems requirements shown in the summary include the 1990 operational date, a spherical configuration reflector, a deployable feed support mast that will hold a set of six line source feeds which rotate around the sphere center, a radiometer frequency range of 1.5 to 120 GHz (which implies very accurate figure control), and a set of four 3-meter-diameter active radars mounted on the satellite structure in order to simultaneously observe the same earth surface area being viewed by the radiometer.

Ten technology areas requiring further development in order to support this "strawman" mission were identified and are listed in the box of the chart. "Modeling and Scaling Laws" and "Ground Test and Validation Facilities" applicable to this spacecraft were again identified as the areas with the earliest need dates. "Long-Life Dimensionally Stable Composites" and "Figure Measurement and Control" are two related technologies which are needed to meet the antenna configuration accuracy requirements. It will be noted that many of the required technologies are repetitions from those established for the Communications Mission example.

# TECHNOLOGY REQUIREMENTS - RADIOMETER

- SPHERICAL ANTENNA RADIOMETER
  - OPERATIONAL 1990
  - 740 KM, 55 DEG ORBIT
  - 50M MICROWAVE REFLECTOR
    - 1.5 TO 120 GHz, 6 FEEDS
    - 29M FEED SUPPORT
  - 3M RADARS (4 PLACES)
  - 5.0 KW POWER REQMT
    - ~100 M$^2$ SOLAR ARRAY
  - MASS ON ORBIT:
    - ~4000 KG (DRY)



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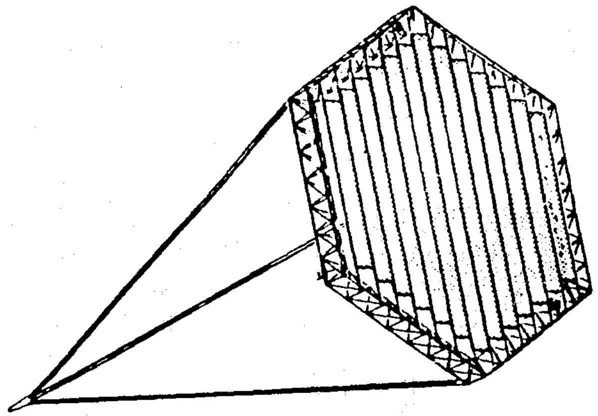
## TECHNOLOGY REQUIREMENTS - RADAR SURVEILLANCE

The largest area space structure selected as a "strawman" design for the present study is the mission added to the original "Scenario A." This is the 180-meter equivalent diameter radar surveillance sensor shown on the opposite sketch. This is a phased array lens-type radar concept currently being investigated by the Air Force/SAMSO. The design illustrated represents a deployable multilayer thin-film sensor attached to a pentahedral cell compression frame surrounding structure. The other major structural element shown is the deployable tripod mast, each leg of which is approximately 450 meters long.

The proposed geosynchronous operational orbit generates a requirement for low thrust orbit transfer propulsion for transfer of this large assembly from the Orbiter-based assembly orbit to the proposed operational orbit. A total of 15 technology needs was identified for this mission example.

# TECHNOLOGY REQUIREMENTS - RADAR SURVEILLANCE

- PHASED ARRAY LENS RADAR
  OPERATIONAL 1990, GEO
  ~180M DIAM SENSOR
  THIN FILM DEPLOYABLE SENSOR
  (700,000 DIPOLES – EACH SURFACE)
  COMPRESSION FRAME STRUCTURE
  DEPLOYABLE TRIPOD MAST
  MASS ON ORBIT ~ 10,000 KG



LARGE PLATFORM ATTITUDE CONTROL ◆
FIGURE MEASUREMENT, ELECT CONT OR ADJUST ◆
POWER CONDUCTORS & CONVERSION ◆
RF PATTERN PREDICTION – PHASED ARRAY ◆
ORBITER ASSEMBLY AIDS ◆
100-300 M ERECTABLE STRUCTURE ◆
100-300 M DEPLOYABLE PHASED ARRAY ◆
200-600 M DEPLOYABLE MAST ◆
MULTIPACTION/EMI SUPPRESSION ◆
ORBITER ASSEMBLY OPERATIONS ◆
LO-THRUST ORBIT TRANSFER PROPULSION ◆
LONG-LIFE DIMENSIONALLY STABLE COMPOSITES ◆
LONG-LIFE POLYMER FILMS ◆
GROUND TEST AND VALIDATION FACILITIES ◆
MODELING AND SCALING LAWS ◆

OPERATIONS

75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
CALENDAR YEAR

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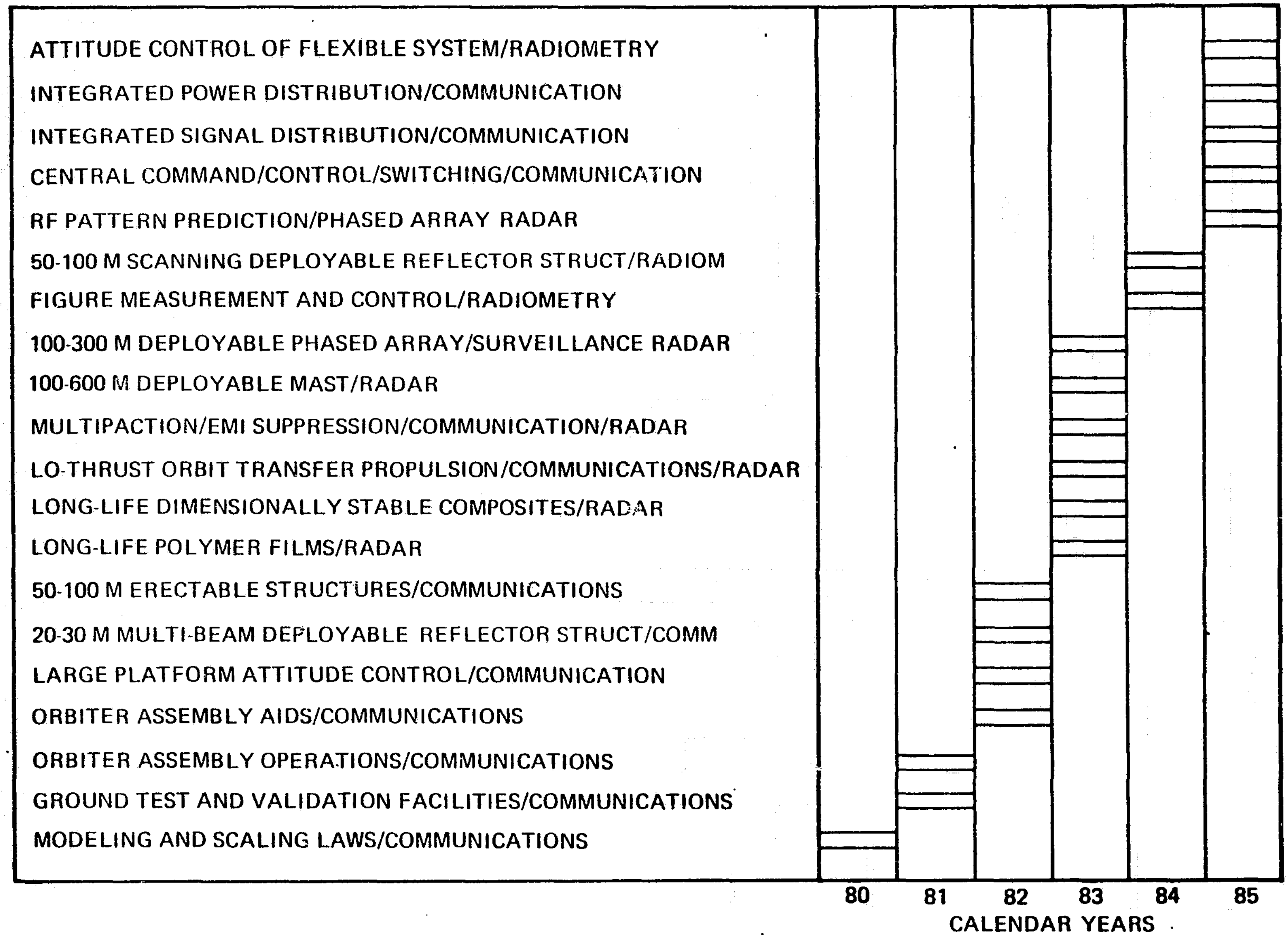
## SUMMARY TECHNOLOGY REQUIREMENTS

The chart summarizes the 20 technology requirements established during the review of the three mission concepts selected as "the scenario" for the study. The calendar years for which the earliest need dates were established are those shown on the chart. The particular mission example which established this earliest need is shown at the end of each of the technology area titles. Further descriptions of the technology problems in each of these areas are given in the following four charts and accompanying text.

It should be mentioned that the earlier technology requirements summary for the communications "strawman" indicated a 1979 need date for the Modeling and Scaling Laws and a 1980 need date for the Ground Test and Validation Facilities. For the early communication's missions these early dates could be useful. However, it is difficult to envision such early accomplishment with the entire program presently in the early planning stages. Therefore, these "need" dates were scheduled for 1980 and 1981, respectively, on the opposite chart and in later discussions.

# SUMMARY TECHNOLOGY REQUIREMENTS



## TECHNOLOGIES REQUIRED

50-100 M Erectable Structures. Large structural platforms (50-100 M) are to be built up from standard structural elements (struts, unions) to produce a lightweight and efficient load-carrying structure to which is attached various equipment/subsystem modules. Structural elements must have a high packaging density for transportation to orbit, and be easily assembled in orbit by remotely operated manipulators without EVA assistance.

20-30 M Multi-Beam Deployable Reflector. Large reflectors required for communication system which can be transported in the Shuttle Orbiter and deployed in orbit. After deployment the reflectors are installed to an erectable structure using remote manipulators. Current systems include the ATS-6 (~10 meters) which have to be extrapolated to 30-M-diameter reflectors. Deployment methods need development for these large systems; consideration should be given to stored energy and mechanically operated actuators.

100-300 M Deployable Ø Array. Technology needs are concerned with development of ultra-thin polymer films, onto which are deposited thousands of dipoles, for the phased array, compacting of the membrane surfaces to a fraction of an inch for efficient stowage, and having the dipole membranes several inches standoff distance from the ground plane when deployed. Phased array blankets require drum storage, deployment mechanisms, and methods for subsequent attachment (structural, electrical signal) of the blankets to adjacent blankets and to the outer structural compression frame.

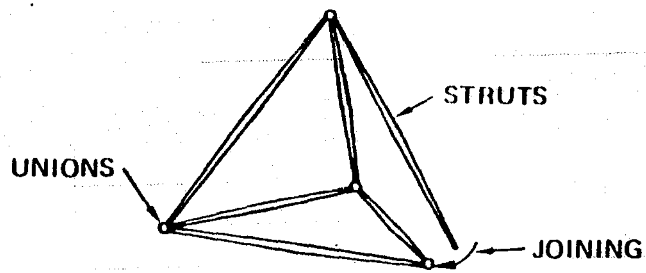
50-100 M Scanning Deployable Reflector. Large diameters will present a packaging and deployment problem at least one order of magnitude more difficult than current deployable reflectors. Surface accuracy measurement and active control are needed to meet some potential mission performance requirements.

Large Platform ACS. The ACS must be capable of controlling a large structural platform, whose inertias are increasing during the orbital assembly operations; the operational inertia being extremely large compared to current satellites. Long-life systems are required (~10 years) and will be installed onto flexible structural elements during on-orbit assembly.

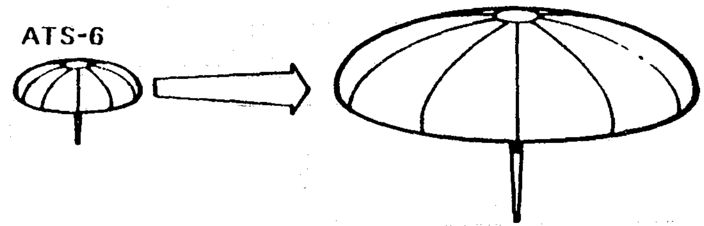
ACS for Flexible Structures. If a 100-percent duty cycle is imposed on the control system, the thermal transients at beginning and end of the eclipse period could result in a control coupling with the structural frequency for erectable platforms larger than 100 meters. A relaxation during the thermal transient period could help uncouple the control system requirements for most of the LSS proposed for this scenario. Concern will be with the response of attaching the controls subsystems to very flexible structural members.

# TECHNOLOGIES REQUIRED

**50-100M ERECTABLE STRUCTURES (1982)**

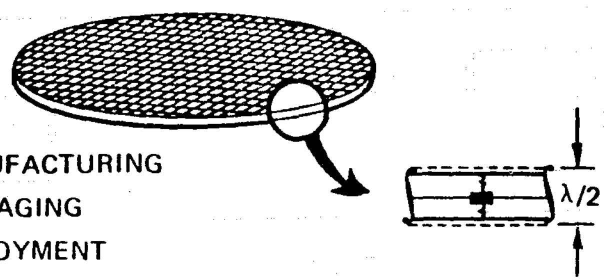



**20-30M MULTI-BEAM DEPLOYABLE REFLECTOR (1982)**



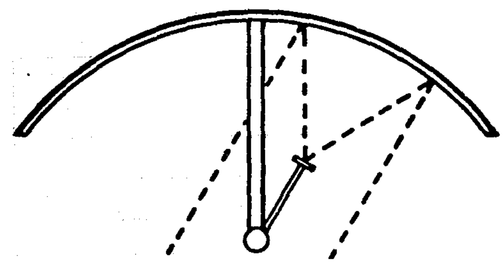

- PACKAGING
- DEPLOYMENT
- ACCURACY

**100-300M DEPLOYABLE $\phi$ ARRAY (1983)**



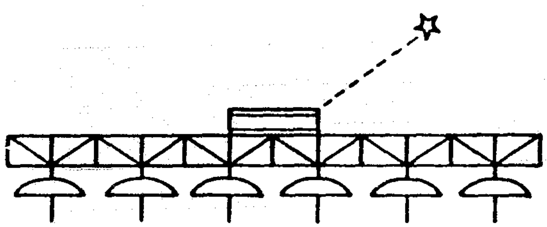

- MANUFACTURING
- PACKAGING
- DEPLOYMENT

**50-100M SCANNING DEPLOYABLE REFLECTOR (1984)**



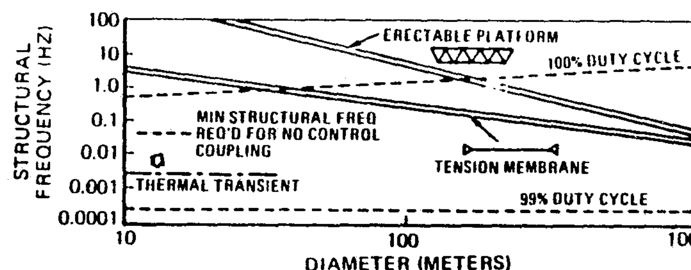
- PACKAGING
- DEPLOYMENT
- ACCURACY

**LARGE PLATFORM ACS (1982)**



- REFERENCE TRANSFER
- SENSOR/ACT. PLACEMENT

**ACS FOR FLEXIBLE STRUCTURES (1985)**




- ADVANCED CONTROL LAWS
- DISTRIBUTED SENSORS/ACTUATORS

## TECHNOLOGIES REQUIRED

RF Pattern Prediction Array (1985). Although the radar lens configuration is relatively forgiving of dimensional tolerances in the assembly process and in deflections due to both natural and induced environments, precision pointing and control of the antenna beam boresight direction is required to meet the most demanding role of space-based radar surveillance missions. RF pattern prediction technologies are required for the flexible space assembled and deployed sensor blankets. Identification of structural blockage from surrounding structural elements and distortion of beam and grating lobes arising from structural/feed/blanket misalignment, and multifunctioning of discrete dipoles or blanket subareas also must be studied.

Orbiter Assembly Aids (1982). The structural assembly aids do not currently exist, although there is current development for the Shuttle Orbiter remote maneuvering system (RSM). The requirements for positional accuracy and duty cycle are more demanding than current RMS specifications. Technology is required in development of dexterous end effectors capable of multiple types of tasks, automated mechanical fixtures for joining, and software to control flexible RMS boom operations in parallel and provide automated collision-avoidance procedures.

Orbiter Assembly Operations (1981). The assembly operations are concerned with the precision maneuvering of flexible structural elements, performing remotely controlled joining operations including the dynamic interaction of two parallel assembly operations. Cell kits can be built with one RMS while simultaneously another manipulator may be required to install kits onto the structural platform. Another important technology area is the dynamics of Orbiter docking to a partially completed structure and the Orbiter's maneuvering (or walking) along the structure during the kit installation operations.

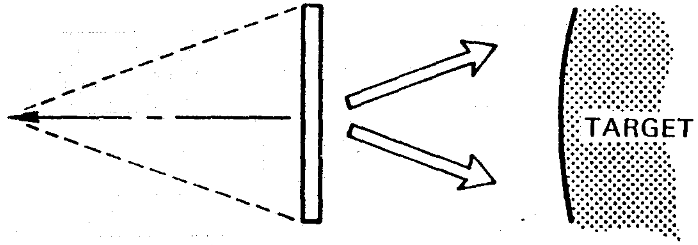
Low-Thrust Orbit Transfer Propulsion (1983). The thrust to weight (T/W) significantly influences the overall system mass for T/W > 0.1 for most large space structures. Since space operational design loads are extremely small, thrust levels must be low in order not to be the predominant design condition, but at the same time they are required to operate at extremely long burn times to compensate for the low T/W. The attachment of the propulsion modules to the individual flexible structural elements and the effect on the propulsion system performance is an important technology consideration.

Ground Test & Validation Facilities (1981). The current ground testing philosophy and facilities appear to be inadequate for full-scale validation of LSS which are extremely difficult to scale down to an amenable size and are designed only to withstand the benign space operational environment design loads. Dynamic characteristics and responses to these large flexible structures will be extremely difficult to simulate with any form of ground testing and could demand mandatory flight experiments of subassemblies to validate any predictive design techniques.

Long-Life Dimensionally Stable Composites (1983). In order to develop lightweight structures that are stable, the use of composites is advocated, but the long-life requirements dictated by the missions require technology developments. Understanding the effects of space duration on composite materials that are cost-effective candidates must be studied. The thermal cycling and transients might necessitate long-life thermal coatings on the structural elements to restrain the overall surface distortions to acceptable limits.

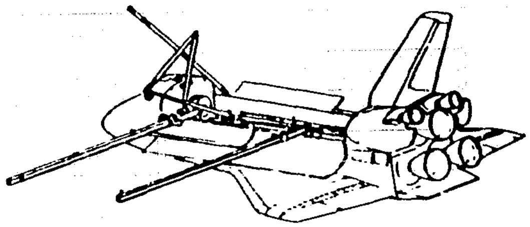
# TECHNOLOGIES REQUIRED

## RF PATTERN PREDICTION ARRAY (1985)



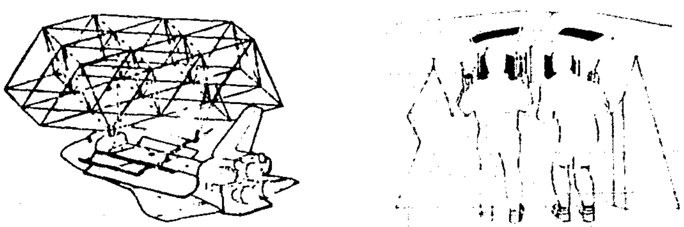

• GRATING LOBES • f/D • STRUCTURAL BLOCKAGE

## ORBITER ASSEMBLY AIDS (1982)



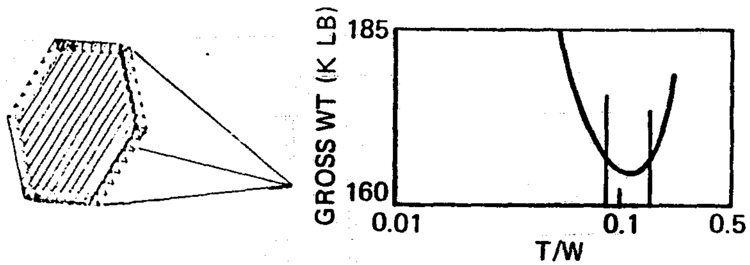
• RMS • EFFECTORS • FIXTURES • SOFTWARE

## ORBITER ASSEMBLY OPERATIONS (1981)



• SEQUENCES • CREW • SOFTWARE

## LO-THRUST ORBIT TRANSFER PROPULSION (1983)




• ENGINE SELECTION • TVC • PLUMES

## GROUND TEST & VALIDATION FACILITIES (1981)

- STRUCTURAL SUB-ASSEMBLIES
- DEPLOYMENT MECHANISMS
- ASSEMBLY AIDS/OPERATIONS
- CREW PERFORMANCE

• FACILITIES • TEST FIXTURES • INSTRUMENTATION

## LONG-LIFE DIMENSIONALLY STABLE COMPOSITES (1983)

- 5–10 YEARS SPACE EXPOSURE
- MINIMUM GAUGE/LAYERS
- SPACE RADIATION EFFECTS ON PHYSICAL PROPERTIES
- THERMAL CYCLING FATIGUE
- ADHESIVE DELAMINATION
- LOW THERMAL EXPANSION
- THERMAL COATING DEGRADATION
- LIGHTWEIGHT-COST EFFECTIVE (CONVENTIONAL - VS - EXOTIC MATERIAL)

## TECHNOLOGIES REQUIRED

100-600 M Deployable Mast (1983). For the scenario proposed there are requirements for long deployable masts that are reasonably stiff to control deflections and displacements of the electronic feed system for the surveillance radar. The packaging efficiency of most current deployable systems is less than 10 percent and, for a one-piece mast of the length required, would exceed the Orbiter's bay length if the current Astromast concept were used. Technology needs should be directed toward other deployable concepts or the on-orbit assembly of deployable segments.

Figure Measurement & Control (1984). The microwave radiometer requirements dictate a large reflector surface where surface quality index ($q \simeq 4.0$) is compatible with the best ground-based systems. A current spaceborne system (ATS-6) has a q-index slightly less than 4.0, but is an order of magnitude less than our proposed reflectors. The environmental perturbations could significantly distort the reflectors requiring active control of the surface. Technology needs are in the area of large surface distortion measurement and actuation for correction during space operation.

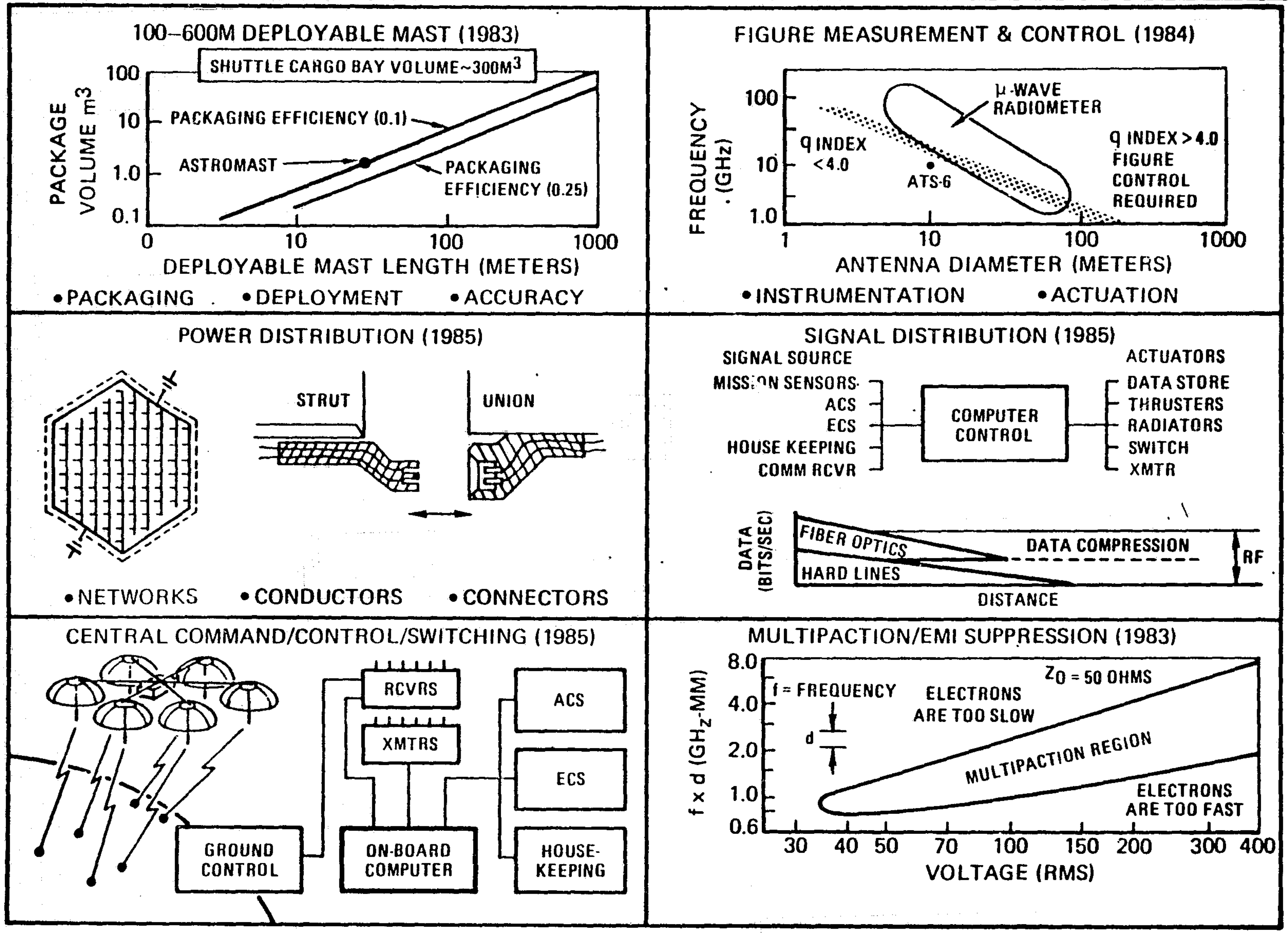
Power Distribution (1985). The concepts proposed for the mission scenario have a series of networks to distribute the power to the many subsystems and sensor elements. The on-orbit assembly and deployment necessitate the remote coupling of numerous connectors. The major technology advancement is for the phased array which will require the deposition of power paths onto thin polymer films, packaging of the sensor blankets without damaging the delicate power networks, deploying and attaching networks to each other, and their successful operation in excess of 10 years in a space environment.

Signal Distribution (1985). Signal distribution technology has similar problems to the power distribution case, but other options are available such as fiber optics and RF transmission, depending on the data rate and transmission distance.

Central Command/Control/Switching (1985). The requirements for the multi-beam concepts for the electronic mail will require the equivalent of a lightweight/long-life automated telephone switchboard in orbit. The modeling of the structure distortion from in-flight measurement and subsequent control logic will necessitate advances in on-board computer capability, reliability, and software sophistication.

Multipaction/EMI Suppression (1983). The technology requirements for multipaction and EMI suppression design evaluation are fairly well understood currently, and will need only careful attention to specific recognizable design details for the proposed vehicle concepts. All of the concepts are low-energy intensity applications and high frequency, which will help avoid the multipaction region.

# TECHNOLOGIES REQUIRED

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## TECHNOLOGIES REQUIRED

### Long-Life Polymer Films (1983)

Long-life polymer films become an extremely important technology challenge for the radar mission application. Extremely thin films are required with 10- to 20-year lifetimes desired. The films also need to withstand handling for packaging within the Orbiter, deployment from the Orbiter after reaching the assembly orbit, and maintaining the deployed structural configuration during transfer to the operational orbit. Other technology complexities involving the thin films include metallic deposition operations and the distribution of reliable electrical circuitry throughout the large areas of polymer film based antenna.

### Modeling and Scaling Laws (1980)

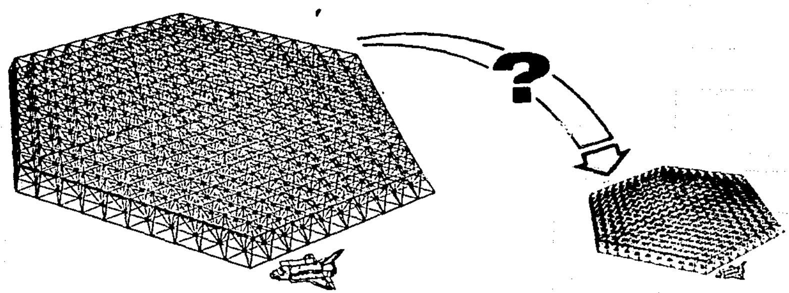
Modeling and scaling laws, as mentioned earlier, is a technology area with the earliest need date of the 20 composite technology requirements. The large-size structures make full-scale testing (either on ground or in space) difficult and expensive, so reliable modeling and scaling laws will be of great assistance in most of the other technology areas. The most crucial modeling developments can be in the thermal prediction and structural response areas. Scaling becomes difficult when the full-size structural components are already designed for very thin walls and thin films. The prediction of the effects of structure joint clearances from small sections of large space structures also presents problems requiring careful analysis of the predictive reliability.

# TECHNOLOGIES REQUIRED

LONG-LIFE POLYMER FILMS (1983)

- $10^{-3} - 10^{-2}$ MM
- 10 – 20 YEARS
- PACKAGABLE/DEPLOYABLE
- ELECTRICAL CHARGING
- METALLIC DEPOSITION

MODELING AND SCALING LAWS (1980)

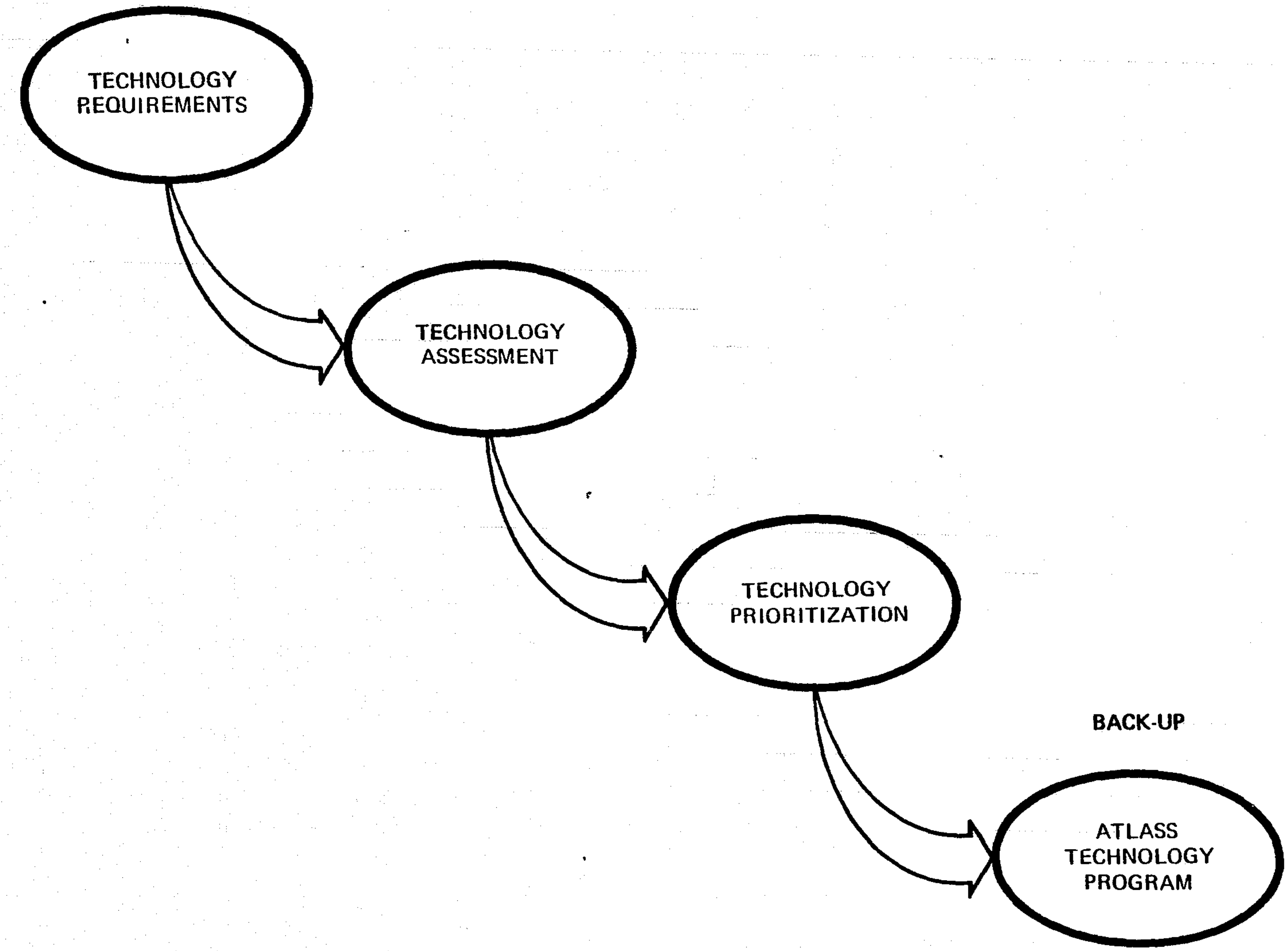



- THERMAL/STRUCTURE
- GAGES
- JOINTS

## METHOD - CHART 2

The second major study analysis area was that of "technology assessment" and "technology prioritization" for each of the systems technologies which were estimated to require further development. The opposite chart presents a simplified logic for the study process. Backup materials which relate these study areas to the ATLASS technology program are presented in Appendices B and C. The next two charts explain further the technology assessment techniques used in the study, and the four following charts (together with their text) provide further detail discussions relating to each of the technology requirements subjects shown in the earlier charts.

# METHOD - CHART 2



## ASSESSING THE TECHNOLOGY

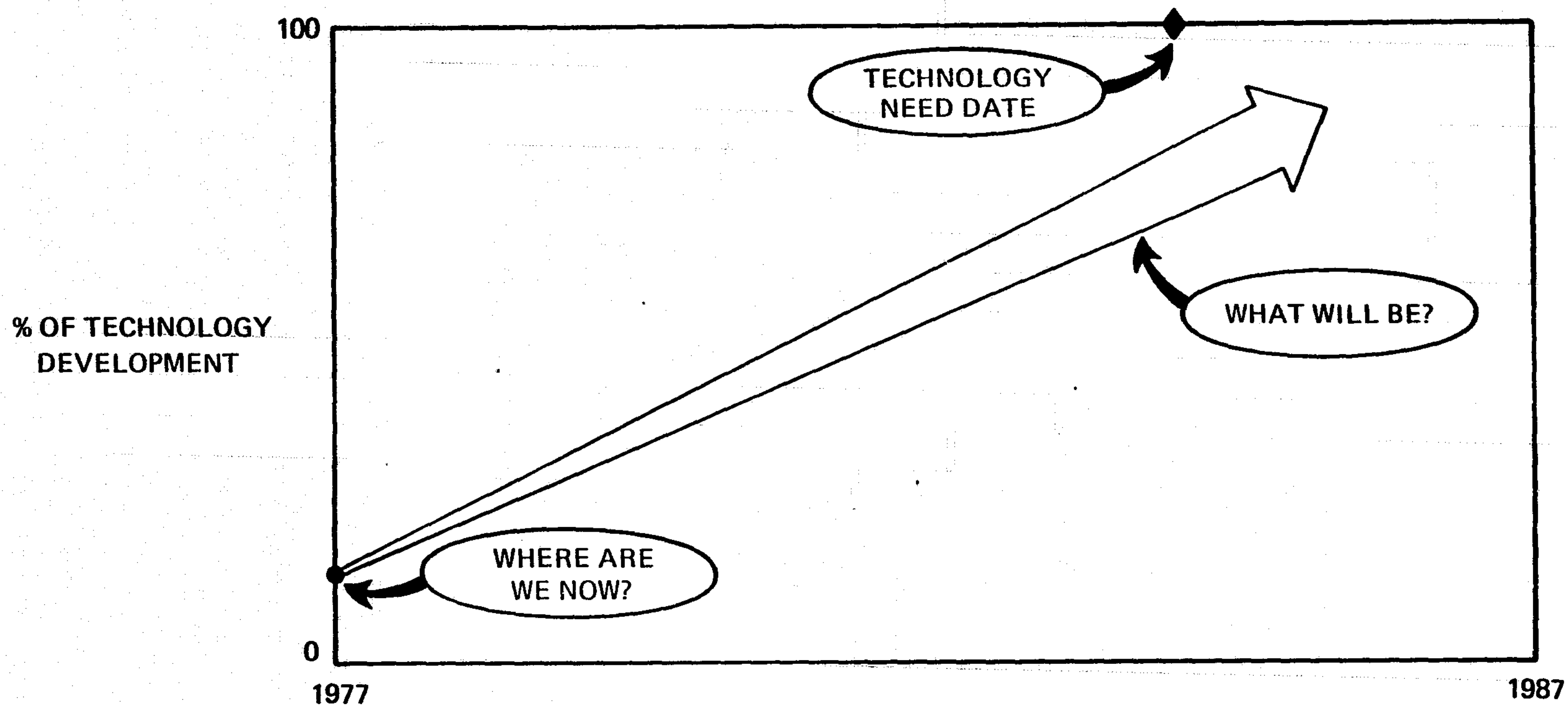
The chart illustrates the format on which all of the technology development assessments were summarized. The methodology for the technology assessment was essentially a modification of that used in the NASA *Outlook for Space* study where the potential future development of technologies were predicted by "groups" of specialists in a number of space-related technology areas. In the present technology assessment study, the review process was limited to the Rockwell Space Division technology specialists most knowledgeable in each of the 20 technology topics identified earlier.

The study asked two questions relative to each technology: *(1) Where are we now?* and *(2) What will be?* These questions relate to the "experts" opinion on the degree of technology development required to support the space scenario (three strawmen) previously described. The "where are we in 1977" was plotted on the ordinate bar of the chart as a percentage of the final technology level required. This value varied from almost zero in some of the least studied areas to 70 percent or more for some areas where only moderate adaptations to existing technologies may be required.

The *"what will be"* question was related primarily to an estimate of the present rate of technology progress in the given technology area. This rate of progress was extrapolated to determine an estimated date at which the required level of technology would be achieved. In some areas, the *"what will be"* arrow reached the 100 percent level, well ahead of the "technology need date." The cases where the need date occurs prior to the achievement date provide an estimate of those areas where accelerated development will be required. It must be noted that all these estimates are based on a limited space scenario and only preliminary estimates of system requirements. The subject will also be discussed further in the later charts summarizing a priority ranking of the technologies.

# ASSESSING THE TECHNOLOGY

- METHOD: NASA OUTLOOK FOR SPACE




- EVALUATORS: ROCKWELL SPACE DIVISION SPECIALISTS

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## ROCKWELL SPACE DIVISION EVALUATORS

The opposite chart provides a listing of the Rockwell Space Division specialists who were asked to evaluate and estimate the technology status of each of the technology areas selected to support the large area space systems scenario. These specialists also were consulted in the preparation of a matrix which related the given technology areas with the ATLASS program proposed organization. This matrix is included in Appendix B.

# ROCKWELL SPACE DIVISION EVALUATORS

ERECTABLE STRUCTURES/N. SMITH

DEPLOYABLE REFLECTORS/A. LOVE

DEPLOYABLE PH ARRAYS/R. DONNOVAN

DEPLOYABLE MASTS/A. LEFEVER

ATTITUDE CONTROL/R. OGLEVIE

FIGURE MEASUREMENT/R. OGLEVIE

FIGURE CONTROL/R. OGLEVIE

POWER CONV & DISTR/K. RUSSELL

RF FIELD PREDICTIONS/R. SCOTT

SIGNAL DISTR/K. RUSSELL

ORBITER ASSY OPS/A. LILLENAS

ORBITER ASSY AIDS/R. TOTAH

MULTIPACTION/EMF SUPPRESSION/R. SCOTT

CENTRALIZED COMM/CONTR/SWITCHING/R. SCOTT

LO-THRUST PROPULSION/R. YEE

LONG-LIFE COMPOSITES/L. BISSING

LONG-LIFE POLYMER FILMS/L. BISSING

GROUND TEST & VALID. FACILITIES/J. BODDY

MODELING & SCALING LAWS/T. NISHIMOTO

## TECHNOLOGY ASSESSMENTS

50-100 M Erectable Structures. Initial start on technology development at NASA-Langley for the design and testing of representative structural members. Design requirements have been considered for the union elements. Current suggested activity will provide the technology and design knowledge derived from the macro-structures concepts (struts, unions, tetrahedral trusses) during the next four years. Design data will be used to predict the design of large area systems for the ground-assembled and tested macro-structures.

20-30 M Multi-Beam Deployable Reflector. Current state of the art can deploy a 10-m antenna (ATS-6). Technology development over the next five years will provide design capability for larger reflectors. There is need to consider development of multi-feed systems for these large reflectors and the total package steering, both mechanically (gimbaled) and electronically.

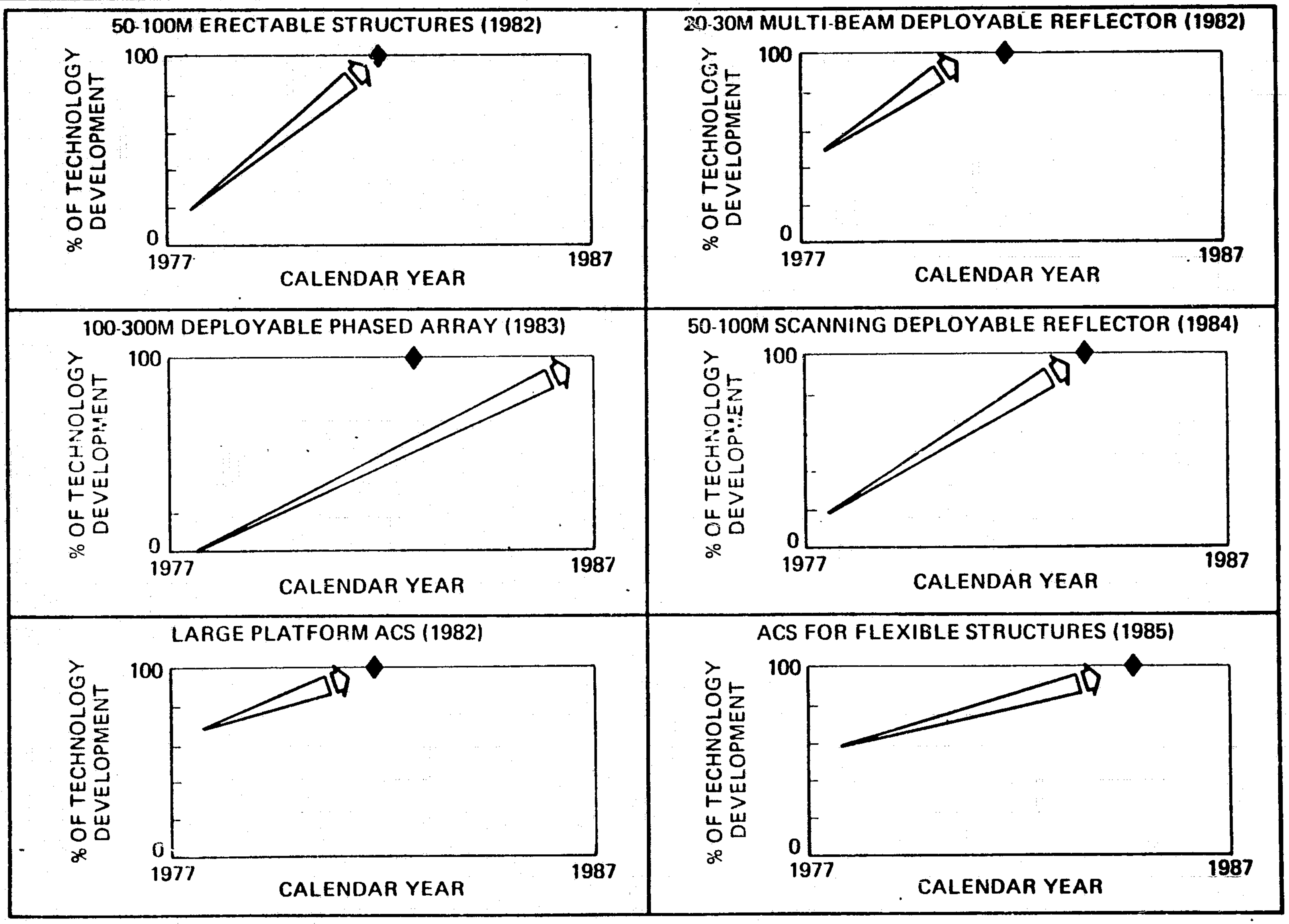
100-300 M Deployable Phased Array. While there is a reasonable degree of technology available for the electrical control of ground-based phased array systems, there is a minimal amount developed for the overall design, structure, manufacturing, and on-orbit assembly of proposed lightweight/flexible tension membranes. The long development schedule results from many interrelated technology functions. These needs are from basic materials (long-life thin polymer film), manufacturing (depositing dipoles onto thin films) all the way to methods of analysis for flexible structures, and on-orbit handling (packaging and deployment) and assembly attachment (structural and electrical).

50-100 M Scanning Deployable Reflector. Less information available than for the smaller multi-beam reflectors. Surface contour accuracy measurement and control systems cannot be effectively evaluated by ground test and will need space validation of potential system concepts for active control. Technology will be available slightly before 1985 with early Shuttle flight technology validation programs.

Large Platform ACS. The platform required for the proposed scenario (communication missions) has moderately coarse pointing requirement, and the structure is stiff enough not to interact with the control system. Current ACS concepts and control laws should apply, requiring moderate advances to handle larger systems with changing inertias and long-life operations.

ACS for Flexible Structures. State-of-the-art control concepts should be applicable; the advances required are due to the large inertias and flexibility inherent in the large space structures. Ground testing, using the highly flexible structures, will be inadequate due to the gravitation effects grossly distorting the structures dynamic responses. Therefore, on-orbit experimental flight testing will be mandatory and will thus delay technology availability to the mid 1980's.

# TECHNOLOGY ASSESSMENTS








Rockwell International
Space Division

# TECHNOLOGY ASSESSMENTS

RF Pattern Prediction, Phase Array (1985). Current technology is capable of predicting RF patterns from well-behaved and "rigid" structures of known configurations which are dimensionally stable. The technology development associated with flexible and environment-induced distorted structures could be available by the early 1980's for the electronic and prediction aspect which excludes the integration of the overall system attitude and electronic control of thousands of individual sensor elements.

Orbiter Assembly Aids (1982). Although some similar ground-based mechanical assembly aids exist, they are significantly different from lightweight operational aids. Technology trends should provide adequate insight and understanding of the design technology requirements for these mechanical assembly aids prior to the need date.

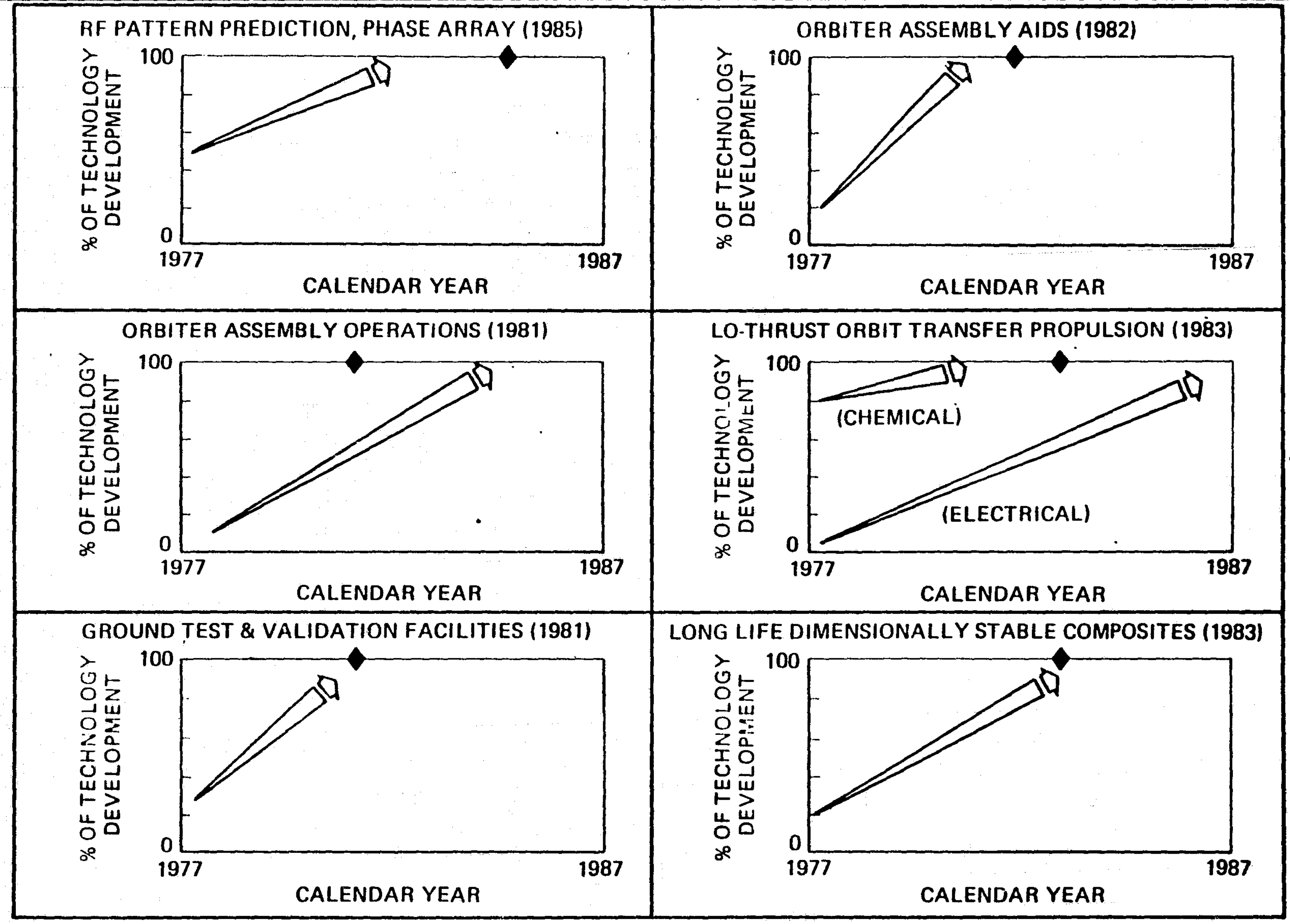
Orbiter Assembly Operations (1981). Currently, the only assembly operations involve EVA-assisted activity and limited ground testing of RMS simulators under psuedo zero-gravity environment. Realistic technology development and validation must involve actual space assembly operations of controlled experiment tests. These validation tests are projected to be accomplished by the mid 1980's. Even with a concentrated schedule, the rate of progress will be limited by the availability of test priorities on the first Shuttle flights starting in 1979.

Low-Thrust Orbit Transfer Propulsion (1983). If it is possible to employ effectively a chemical low-thrust propulsion system, only limited development will be required to obtain the required propulsion technology and it will be available by the early 1980's. If one is forced to use electric propulsion, which is still in the laboratory stage of development for extremely small systems, then the development trends indicate availability would be delayed until the latter half of the 1980's.

Ground Test & Validation Facilities (1981). Although testing of the basic structural elements can be accomplished by current ground testing techniques, advances are required in handling the testing of the large flexible subassemblies and simulation of a zero-gravity environment with realistic thermal and vacuum environments. Projected trends in technology advancement, underway at NASA-Langley, indicate that the testing requirements peculiar to LSS are being understood and gradually developed and should be available by the need date.

Long-Life Dimensionally Stable Composites (1983). Very limited knowledge is available on the long life of structural composites and thermal coatings for on-orbit life in excess of 10 years, as the mission scenarios dictate. Technology development is planned already for the long-duration exposure facility (LDEF), transported into orbit and revisited by the Orbiter. The planned LDEF launch date and a reasonable exposure time (and subsequent extrapolation) should provide technology in the mid 1980's.

# TECHNOLOGY ASSESSMENTS



## TECHNOLOGY ASSESSMENTS

100-600 M Deployable Masts (1983). Although deployable Astromast technology is available, their length limitation is controlled by the Orbiter's bay length and is insufficient to meet the mast length required for the radar surveillance application. Therefore, different packaging concepts are required with higher packaging efficiencies. Due to the lightweight and flexible nature of the masts, their deployment technology must be validated by on-orbit testing before being employed in the operational design.

Figure Measurement & Control (1984). Only limited current knowledge is available for flexible ground-based systems. Due to the large reflectors inability to withstand the earth's gravity, most technology development and validation have to be accomplished with on-orbit testing. Slow trend advancement is associated with the needs for advances in several areas such as on-orbit measurement systems for reflector distortions, simplified modeling to represent a complex structure of hundreds of elements, and control laws and actuator systems to control a highly flexible structure.

Power Distribution (1985). Although power distribution concepts are operating in space, the current technology base does not address the problems associated with on-orbit assembly and numerous power distribution sub-networks and their installation to extremely thin-membrane surfaces. The development schedule should provide capability prior to mission concept development need date requirements.

Signal Distribution (1985). The current status deals with hardwire signal systems. Development is progressing with fiber optic concepts, the major problem being multiple connections of cable-to-cable or cable-to-device. Such connections are fairly intolerant to misalignment of fiber connections, even for the high-loss fiber cables which are useful for lengths less than 30 meters. Light signals are not affected by EMI from nearby sources.

Centralized Command/Control/Switching (1985). Current ground-based computer systems technology is capable of handling the major technology requirements. The need will be to provide software systems and hardware with the capacity and speed to fulfill the mission requirements with on-board systems. The trend from Apollo to the Shuttle Orbiter is indicative of the advance rate necessary to meet the current scenario requirements.

Multipaction/EMI Suppression (1983). A good deal of current technology is directly apropos to the proposed system concepts with careful attention in designing around problem areas. Current technology trends seem adequate in understanding the majority of the problems associated with these low-power/high-frequency systems.

# TECHNOLOGY ASSESSMENTS

100-600M DEPLOYABLE MASTS (1983)

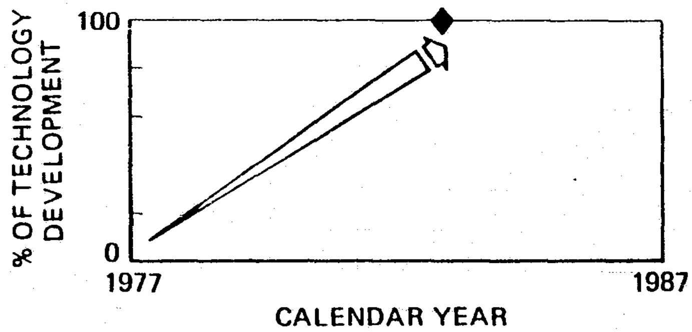
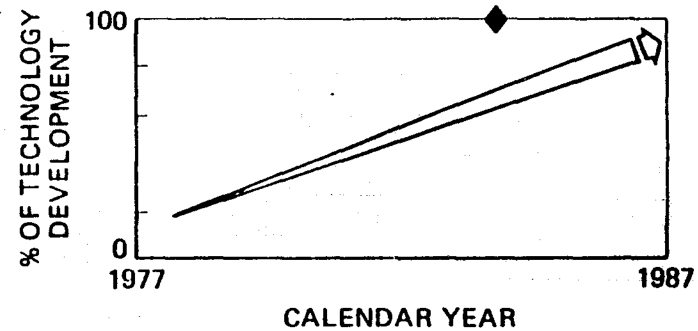
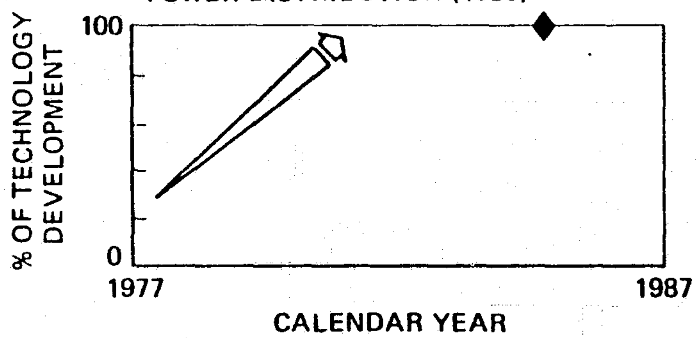


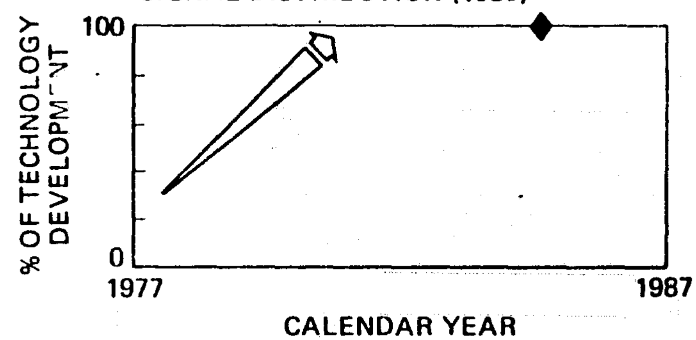

FIGURE MEASUREMENT & CONTROL (1984)



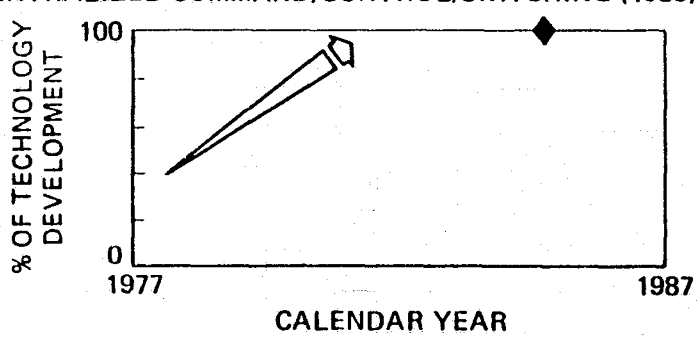

POWER DISTRIBUTION (1985)



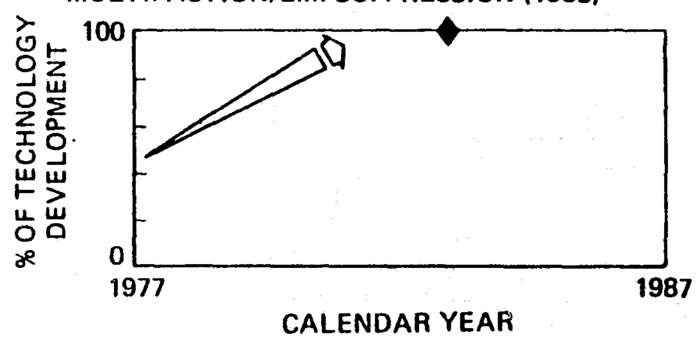

SIGNAL DISTRIBUTION (1985)




CENTRALIZED COMMAND/CONTROL/SWITCHING (1985)




MULTIPACTION/EMI SUPPRESSION (1983)



## TECHNOLOGY ASSESSMENTS

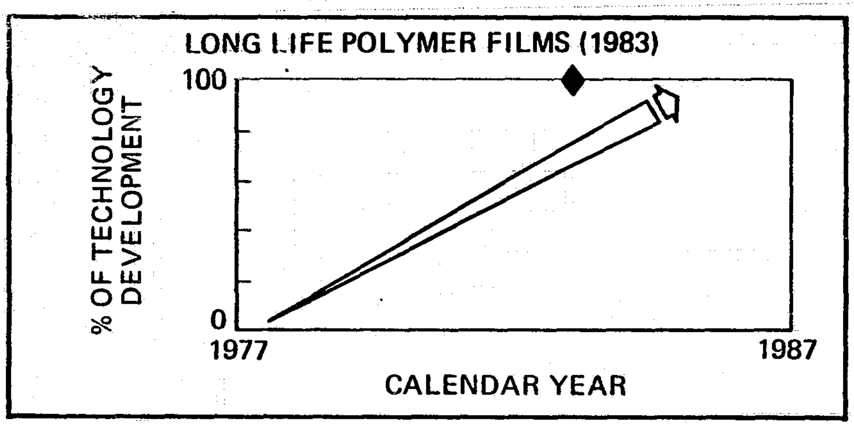
### Long-Life Polymer Films (1983)

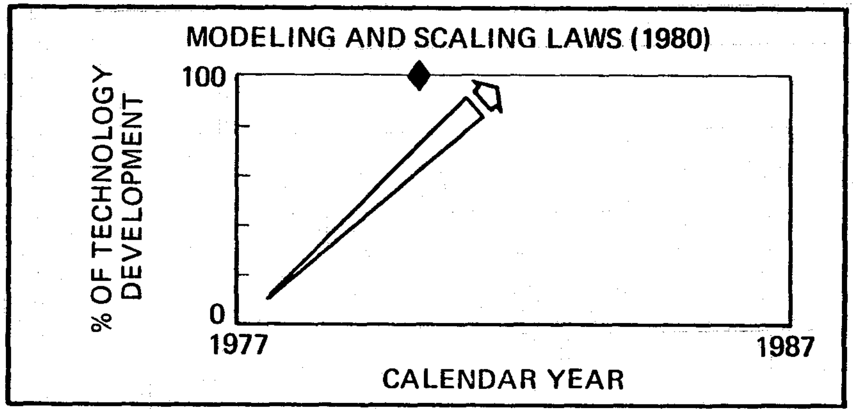
Long-life polymer film technology is not well understood for the application suggested in the study scenario. The extremely thin gauges required for the material, plus the severe handling problems during the radar lens manufacture and deployment, result in an estimation of an eight-year development program at the presently predicted rate of progress. This would be two years later than the established need date.

### Modeling and Scaling Laws (1980)

Modeling and scaling laws technology has had a good deal of study for many space projects, but is not believed to be well understood for the large area space structures or for the applications suggested in the study scenario. The present rate of progress in this technology area was estimated to reach the required level in approximately five years. This, again, would be about two years behind the need date. Thus, accelerated development would be required in this area in support of the study scenario.

# TECHNOLOGY ASSESSMENTS



## PRIORITY RATING METHODOLOGY

The study of the technology requirements and the technology assessment was continued with a simplified "priority rating" determination. Its purpose was to provide a first-cut at selecting from the 20 identified technology areas those requiring the earliest and most urgent attention. Two questions were used to separate the technologies into four possible categories. The questions and the priority categories are shown on the chart matrix.

The highest priority category is thus represented by a technology for which there were no viable alternatives to the selected technology approach. The second qualification for the highest priority rating was that the predicted technology growth rate would not achieve the required 100-percent level by the "need date" estimated for each technology. In a similar manner, the lowest priority rating was given to those technologies for which alternative technology approaches were estimated as available and a satisfactory growth rate was predicted.

All of the determinations for this exercise were highly judgmental and were accomplished by the systems engineers assigned to the study. Again, it must be remembered that all the determinations are related to the three representative missions of the scenario, and that only the preliminary system requirements are presently available. The results of the priority ratings are summarized on the following chart.

# PRIORITY RATING METHOLOGY

| PRIORITY CATEGORY | QUESTION 1: ARE THERE VIABLE ALTERNATIVES IF THE NEED IS UNSATISFIED? | QUESTION 2: COULD THE REQUIRED NEED DATE BE SATISFIED BY THE ON-GOING TECHNOLOGY RATE/TREND LINE? |
|---|---|---|
| 1. HIGHEST | NO | NO |
| 2. NEXT HIGHEST | NO | YES |
| 3. NEXT HIGHEST | YES | NO |
| 4. LOWEST | YES | YES |

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## TECHNOLOGY PRIORITY SUMMARY

The application of the previously described priority rating methodology resulted in determining four technologies with the highest Priority 1, six technologies with Priority 2, three with Priority 3, and seven with the lowest Priority 4. Again, it must be repeated that this set of priority results is based on this particular scenario and our assessment of how the technology is evolving. The technology assessment was on "will be" estimations. All the technology developments "can be" accelerated. The various specialists concurred that with high priority attention and support the total scenario can be satisfactorily accomplished.

The "100-300 M deployable phased array" technology is the first-listed item in the Priority 1 summary. This is a unique design with no known viable alternatives that will provide the same sensor data performance. The many development problems in handling and packaging, as well as the electronics, of this application resulted in an estimate of a required development date well beyond the need date. Similar analyses summaries were made for all of the technologies. The complete set is summarized in the backup material in the study report.

The priority classifications do not necessarily imply that the higher ranked priorities will require more time and other resources for development. For example, the "50-100 M deployable reflector" development may well require considerably more man-hours and facilities and other resources than that required for the "modeling and scaling laws" development, which is in the Priority 1 category. The priority drivers in these cases are the need dates--1980 for the scaling laws versus 1984 for the reflector technology design guidelines. There also are other important interrelationships between the many technology areas that cannot be adequately portrayed in the present simplified analysis. All the areas need further studies to provide the necessary details of the level and magnitude of each of the development tasks.

# TECHNOLOGY PRIORITY SUMMARY

| | |
|---|---|
| PRIORITY 1 | • 100-300M DEPLOYABLE PHASED ARRAY<br>• ORBITER ASSEMBLY OPERATIONS<br>• FIGURE MEASUREMENT AND CONTROL<br>• MODELING AND SCALING LAWS |
| PRIORITY 2 | • 50-100M ERECTABLE STRUCTURES<br>• 20-30M MULTIBEAM DEPLOYABLE REFLECTOR<br>• LARGE PLATFORM ACS<br>• ACS FOR FLEXIBLE STRUCTURES<br>• RF PATTERN PREDICTION, PHASED ARRAY<br>• POWER DISTRIBUTION |
| PRIORITY 3 | • LONG-LIFE DIMENSIONALLY STABLE COMPOSITES<br>• 100-600M DEPLOYABLE MASTS<br>• LONG-LIFE POLYMER FILM |
| PRIORITY 4 | • 50-100M DEPLOYABLE REFLECTOR<br>• ORBITER ASSEMBLY AIDS<br>• LOW-THRUST PROPULSION<br>• GROUND TEST AND VALIDATION<br>• SIGNAL DISTRIBUTION<br>• CENTRALIZED COMMAND/CONTROL/SWITCHING<br>• MULTIPACTION/EMI SUPPRESSION |

## CONCLUSIONS

Three conclusions from the present study are summarized on the chart. The 20 technology needs identified are believed to provide a good cross-section of the types of technologies which will be required to support the future large area space structures missions. It must be noted that the scenario for our present study did not include the potential requirements for the development of the Solar Power Satellites which also are under intensive investigation throughout the aerospace industry.

Out of the 20 technology requirements determined in the early part of the study, there were four given a highest priority rating by the study methodology. These four, noted on the previous chart, then represented cases where no viable alternatives to the technology were available. In addition, each of the four technologies was estimated to require a higher level of support than presently predicted for the coming years in order to achieve technology levels required for the study scenario space missions.

"Modeling and Scaling Laws" technology represents the item in the top priority group, and also has the earliest need date estimated as 1980. The development of good predictive techniques for the application to the large area space structures appeared to the study analysts to be extremely important. The large dimensions of supporting structures make full-scale ground testing more difficult than in present-day applications. The surface accuracy required of large area reflective sensors operating in the microwave frequencies makes figure measurement and control an important interfacing technology with the "scaling laws." In a similar manner, the "scaling laws" support many--if not all--of the total technology requirements. This area then can be one which should have the most urgent attention, even prior to the establishment of the approved list of the coming large area space structure supported space activities.

# CONCLUSIONS

1. TWENTY TECHNOLOGY NEEDS HAVE BEEN IDENTIFIED, THESE NEEDS ARE ALL REQUIRED TO SUPPORT THE IMPLEMENTATION OF A POSSIBLE SCENARIO OF LARGE SPACE STRUCTURE MISSIONS TO BE FLOWN BEFORE THE END OF THE CENTURY.

2. OF THESE NEEDS, FOUR WERE IDENTIFIED AS HAVING NO VIABLE ALTERNATIVES AND AS PRESENTLY BEING UNDERSUPPORTED IN TERMS OF ACHIEVING REQUIRED TECHNOLOGY LEVELS BY THE REQUIRED NEED DATE.

3. MODELING AND SCALING LAWS TECHNOLOGY WAS INCLUDED IN THE HIGHEST PRIORITY GROUP AND ALSO WAS AN ITEM WITH THE EARLIEST NEED DATE (1980). DEVELOPMENT OF RELIABLE PREDICTIVE TECHNIQUES IS NEEDED TO SUPPORT MANY OTHER TECHNOLOGY AREAS.

# APPENDIX A
# SCENARIO DEFINITIONS

## INTRODUCTION

Appendix A provides a brief summary of the "Scenario A" missions which were referenced in the study as a starting point for selecting the current study scenario. From this second scenario, a set of suggested ATLASS program requirements was derived. The "Scenario A" missions consist of postulated extended manned space activities for the 1985 to 1995 time period and were included in a Rockwell International Space Division briefing document, PD 77-20, *Extended Manned Space Activities Status Report*, June 13, 1977.

The appendix also provides some further data and discussion of the eight missions shown on the "Prospective Mission Scenario" chart of the current report (see pages 6 and 7). These two general areas are described further in the next sections.

## "SCENARIO A" SUMMARY

The objective of the Extended Manned Space Activities study, reported in the Rockwell International Space Division brochure report, PD 77-20, was to review potential manned space programs for the 1985 to 1995 decade. The overall objectives for that study are summarized in Table A-1.

Table A-1. Extended Manned Space Activities Study Objectives (PD 77-20)

A. To assist NASA in defining the future of the orbital manned space program accounting for:
   - The missions and their requirements
   - The restrictions of budget
   - Full use of existing hardware

B. To gain insight into the potential effects of variations in space construction methods:
   - Full EVA to full automation

C. To identify potential change requirements to Shuttle:
   - Extended duration
   - Station tending
   - Habitability

The basic study approach used in their definition of the manned space missions is summarized in Table A-2. It will be noted that the approach was

tailored to use the Shuttle Orbiter to the extent practical as the operating base for extended-duration manned missions and for construction of the larger space structures which may be required.

Table A-2. Basic Study Approach (PD 77-20)

1. Define a space program requiring man's long-term presence.
2. Utilize Shuttle, conventional and extended duration, to the limit of its capacities.
3. Only then, add other vehicles and/or systems to complement existing hardware.
4. Ascertain the full usefulness of the system at each step or phase.

The future manned missions for the time period being considered were expected to have an industrial and public services orientation. In many present space studies, the most prominent future space missions are those concerning space power satellites (SPS). These tend to become objectives which overshadow all other space activities and would present a tremendously large development cost. The study, therefore, proposed two potential scenarios, one with and one without the SPS. The major drivers and secondary activities estimated for these scenarios are indicated in Table A-3.

Table A-3. Industrial and Public Services Orientation Alternative Scenarios

PROGRAM/SCENARIO A - WITHOUT SPS

| | |
|---|---|
| Drivers: | Space Processing and Commercial Production<br>Public Services and Communications |
| Secondary: | Solar Terrestrial Observation and Climatology<br>Life Sciences |

PROGRAM/SCENARIO B - WITH SPS

| | |
|---|---|
| Drivers: | Solar Power Satellite (SPS) R&D |
| Secondary: | Life Sciences<br>Space Processing and<br>Public Services and Communications<br>Solar Terrestrial Observation and Climatology |

Approach: PROGRAM REQUIREMENTS + BUDGET → SYSTEMS / SCHEDULES / SEQUENCES

The scenario selected as the "starting point" for the ATLASS Program Requirements study was the first which is designated as "Scenario A." The

objectives and estimated summary data for the four general areas of "Scenario A" are summarized in Table A-4. The first (Space Processing) and the last (Life Sciences) of the four areas are space missions which were estimated to utilize modular "space station" type facilities and, therefore, are not particularly relevant to the type of large area space structures to be studied in the ATLASS program.

Table A-4. "Scenario A" Summary (Without SPS)

| | |
|---|---|
| **SPACE PROCESSING** | |
| Objective: | Develop medicines/pharmaceuticals, metals/materials, crystals/glasses/ceramics of commercial value for public benefit. |
| Process: | Gradually increasing R&D and commercial prototype activity. Production sponsored by private industry. |
| Statistics: | Up to 6000 kg mass on orbit<br>30 $m^3$ equipment volume<br>~14 kW electric power<br>Six-man crew<br>Up to 15 products in R&D simultaneously<br>Mission investment through 1995 ~$2.5 billion<br>Operations cost through 1995 ~$0.8 billion |
| **PUBLIC COMMUNICATIONS SERVICES** | |
| Objective: | Major improvements in public and personal communications services through the process of complexity transfer from the individual to the central information processor. |
| Process: | Assembly in earth orbit of satellite systems for<br>a. Educational and public TV<br>b. National information system<br>c. Electronic mail<br>d. Personal communications |
| Statistics: | Assembled in earth orbit from prefabricated components and subsystems:<br>a. One flight (1985)<br>b. One flight (1987)<br>c. Two flights (1990)<br>d. Three flights (1993)<br>Mission investment through 1995 ~$3.2 billion<br>Operations cost through 1995 ~$0.8 billion |

--continued on next page

Table A-4. "Scenario A" Summary (Without SPS) (Cont.)

| SOLAR TERRESTRIAL OBSERVATION | |
|---|---|
| Objective: | Develop the technology to permit long-term climatological forecasting (vs. short-term warning) as influenced by the dynamics of the solar-earth system. |
| Process: | Phased introduction of spaceborne instrumentation for measuring solar energetics, solar/earth magnet coupling, earth energy balance, and atmospheric effects. |
| Statistics: | Up to 18,000 kg mass on orbit<br>22 $m^3$ equipment volume<br>~10 kW electric power<br>Four-man crew<br>Two large remote radiometers:<br>One 50-m-diameter at 5000 nmi<br>One 100-m-diameter at GEO<br>Mission investment through 1995 ~$0.65 billion<br>Operations costs through 1995 ~$0.94 billion |
| **LIFE SCIENCES** | |
| Objective: | Determine the effects--beneficial and debilatory--of extended staytimes in space of the biological and physiological characteristics of man, in preparation for future missions, operations and functions, and as an element in therapy. |
| Process: | Continuation of Life Sciences experiments of extended Apollo and Skylab, including introduction of advanced biological process analytic equipment. |
| Statistics: | Up to 6500 kg mass on orbit<br>55 $m^3$ equipment volume<br>~5.5 kW electric power<br>1.5 man crew time equivalent<br>Mission equipment investment through 1995 ~$0.53 billion<br>Operations costs through 1995 ~$0.15 billion |

Similarly, the manned crew indicated for the Solar Terrestrial Observation mission (Area 3) is for the space station type manned laboratory specified for instrument development. However, the two large remote radiometers listed as desirable are the structures which are candidate for space assembly operations. From "Scenario A" the interesting candidates for the ATLASS Program Requirements Study then are the four satellite systems in the Public Communication Services (Area 2) and the two large radiometers. The proposed operational flight dates for candidates are indicated in the upper part of Figure A-1. The lower portion of the figure indicates extended-duration Orbiter availability dates needed to support the schedule. The figure also shows proposed buildup of the space station which could be used for construction support for the larger area space structures as well as performing Space Processing, Scientific Development, and Life Sciences missions.

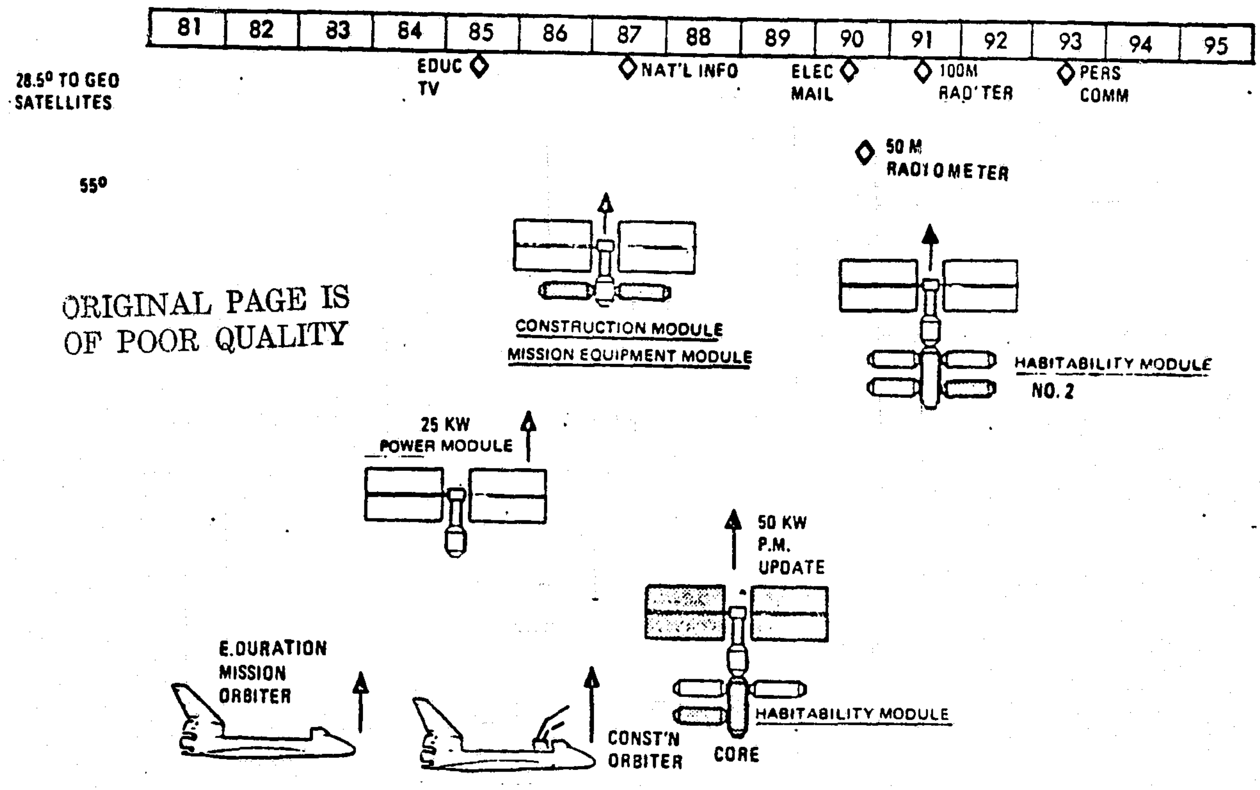


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Figure A-1. "Scenario A" Schedule

PROSPECTIVE MISSION SCENARIO

The following section provides a summary description of each of the eight space missions shown in the study briefing (see page 7 of the report). The chart is repeated here as Figure A-2. The first two items of the figure indicate Shuttle orbital flight tests (OFT) and structural experiment flights which will be precursors to the implementation of the large space structure systems. Four of the prospective missions represent the four public communications services satellites discussed in the previous appendix section: (1) Educational and Public TV, (2) National Information System, (3) Electronic Mail, and (4) Personal Communication Satellites.

Item 7 (Figure A-2) shows a 50-m-diameter radiometer which could perform earth and atmospheric surveillance similar to that of the 50-m radiometer of "Scenario A." Item 6 of the figure shows an addition to the earlier scenario concepts. Item 6 represents a large 180-m microwave surveillance radar which is currently of interest to the Air Force. It was concluded that the large space structure and on-orbit operations assembly requirements would provide an appropriate candidate for consideration in the ATLASS project planning.

Continued analysis of the prospective mission scenario resulted in the selection of three of the missions as adequately representing the range of large area space structure technology problems which would be encountered in the period of interest and limitations of the study. The selected missions

were the Electronic Mail Satellite, representing the communications group (Item 5 of Figure A-2); the 50-m Microwave Radiometer (Item 7); and the Radar Surveillance Satellite (Item 6). These three were explained to a middle level of detail in the briefing brochure section of this report. The following discussions provide a summary of available information and subsystem estimates for all of the eight items on Figure A-2.

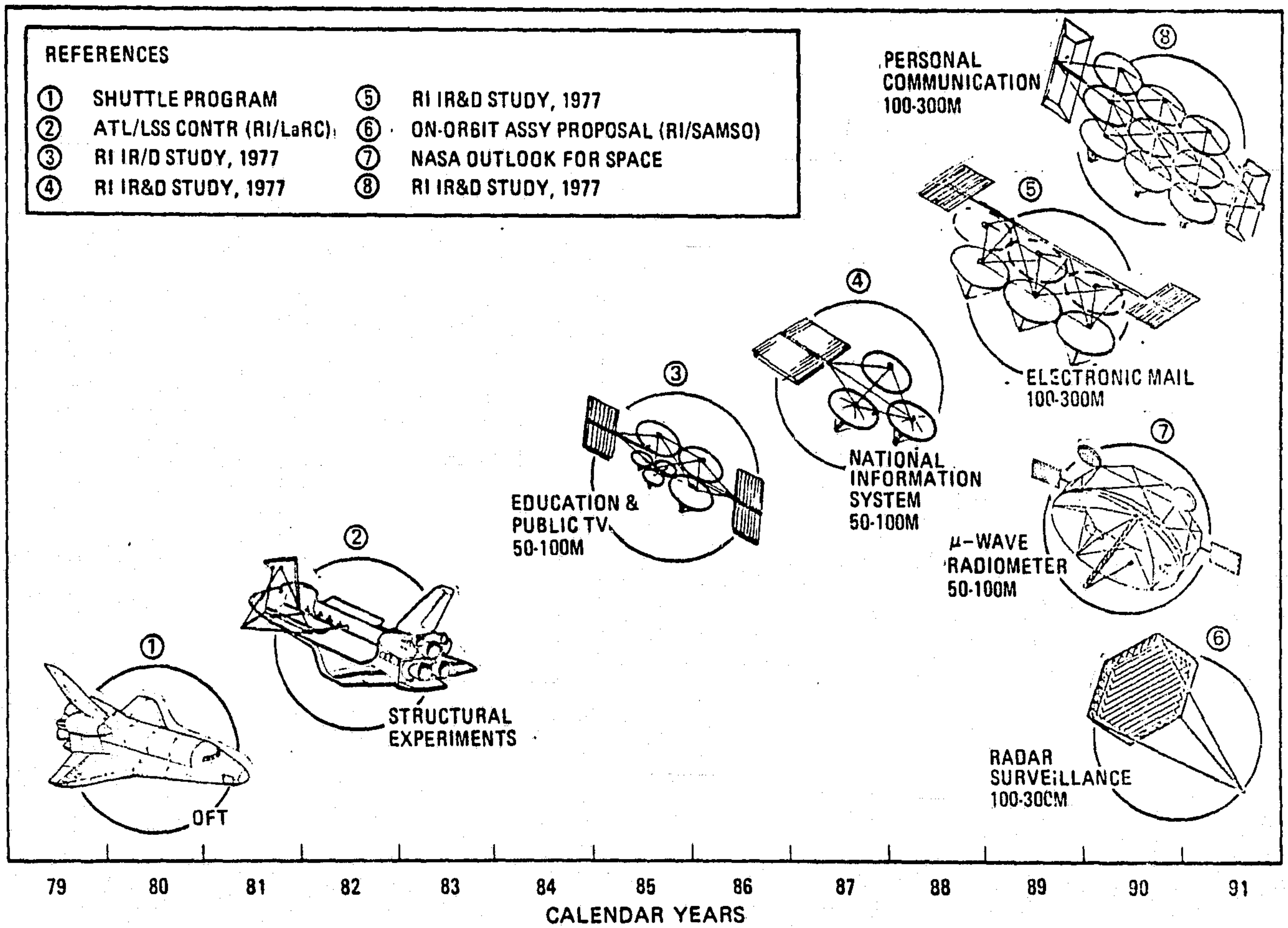



Figure A-2. Prospective Mission Scenario

## Orbital Flight Test Summary

The Orbital Flight Test (OFT) program occurs on the earliest orbital flights of the Shuttle. The major objective of these flights is the final qualification testing of the Orbiter and its subsystems. However, five of the six OFT flights are expected to carry sets of pallet-mounted experiments which can be performed on mission time remaining after the scheduled Orbiter tests are completed. Of most importance to the large space structures technology area will be the first on-orbit testing of the Orbiter remote manipulator system (RMS) which is scheduled to fly on OFT-3 and following flights. The potential remains of proposing tests and test procedures for the OFT flights which could be of benefit to the ATLASS program. Figure A-3 provides an overall summary of the current plans for the OFT program and four following flights.

| CALENDAR YEAR | | ORBITER VEHICLE 102 ORBITAL FLIGHTS 1-10 |
|---|---|---|
| 1979 | 1980 | PAYLOADS/CARGO |
| △ | | 1. DEVELOPMENT FLIGHT INSTRUMENTATION (DFI)/INDUCED ENVIRONMENT CONTAMINATION MONITOR (IECM) |
| △ | | 2. ORBITAL FLIGHT TEST (OFT) PALLET + DFI/IECM |
| △ | | 3. PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM (PDRS) TEST ARTICLE/GSFC EXPERIMENT + DFI/IECM |
| △ | | 4. HYBRID PALLET + DFI/IECM |
| | △ | 5. SKYLAB REBOOST + DFI/IECM |
| | △ | 6. SYNCOM IV + PALLET + DFI/IECM OR SYNCOM IV + MODULAR MULTIMISSION SPACECRAFT (MMS) + DFI/IECM |
| | △ | 7. LONG DURATION EXPOSURE FACILITY (LDEF) + OFT PALLET |
| | △ | 8. TRACKING AND DATA RELAY SATELLITE (TDRS)/SATELLITE BUSINESS SYSTEMS (SBS-A) ON SPINNING SOLID UPPER STAGE (SSUS-D) |
| | △ | 9. PALLET + PALLET + GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (GOES-D)/SSUS-A + ANIK-C/1/SSUS-D |
| | △ | 10. TDRS-B/INTERIM UPPER STAGE (IUS) + SBS-B/SSUS-D |

Figure A-3. Orbiter Early Payloads Planning

Structural Experiments Summary

Figure A-4 illustrates the concept of a structural experiment recommended as a flight test candidate designated as TV-2 (Technology Verification Experiment No. 2) in Part 3 of the ATL/LSS study.[1] This experiment would test a

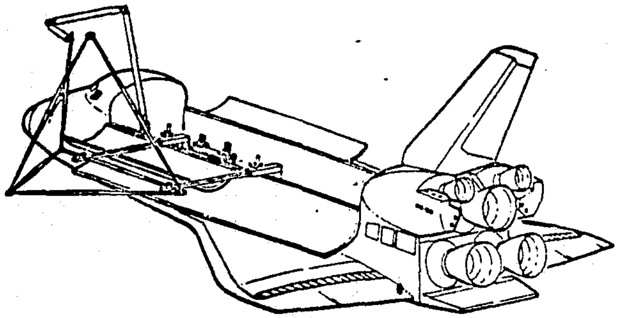



Figure A-4. Structural Experiment - Cell Assembly

large space structures assembly technique by constructing a basic tetrahedral structural cell. The test would utilize some of the proposed construction aids considered for large platform construction. The test also could include the installation of payload equipment onto the apex of the tetrahedral cell. Other tests could be performed to validate structural model assumptions (thermal, vibration, etc.), and to obtain data on operational assembly times for typical assembly operations.

Table A-5 summarizes the estimated resource requirements for all three of the flight experiments recommended in the reference study. Figure A-5 illustrates the estimated TV-2 development schedule, also taken from the reference report. This schedule shows some of the structure and assembly aid components which could be tested on TV-2. The experiment was estimated to require 12 hours of mission time as shown on the resource requirements table.

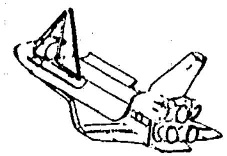
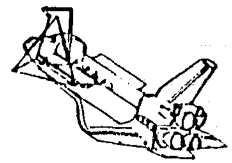
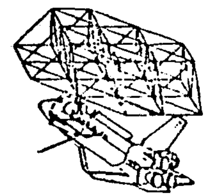
Educational TV Summary

The sketch, Figure A-6, represents the smallest of the communication satellites considered for "Scenario A." The operational orbit would be at geosynchronous (GEO) altitude and at a longitude appropriate for the earth surface area to be served. The figure indicates some of the pertinent system characteristics estimated for the design. The 5-ft parabolic receiving antennas are the ground terminals of the data relay system.

The requirements for three 0.7-m-diameter antennas will allow the basic structure and electronics to be assembled prior to Orbiter launch. The operating power requirements of approximately 15 kW will require a solar array of

[1]Report SD 77-AP-0071, Volumes 1 and 2, Rockwell International/ Space Division, June 1977.

Table A-5. Structural Experiments Resource Requirements

| RESOURCE REQUIREMENT |  TV-1 |  TV-2 |  TV-3 |
|---|---|---|---|
| MASS (kg) | 259 | 562 | 10,957 |
| VOLUME ($m^3$) | — | — | 60 |
| POWER (WATTS) | < 1000 | < 1000 | ~2000 |
| ENERGY (kwh) | 7 | 14 | ~200 |
| ALTITUDE (km) | ANY | ANY | ~550 |
| MISSION (hr) | 6 | 12 | 78 |

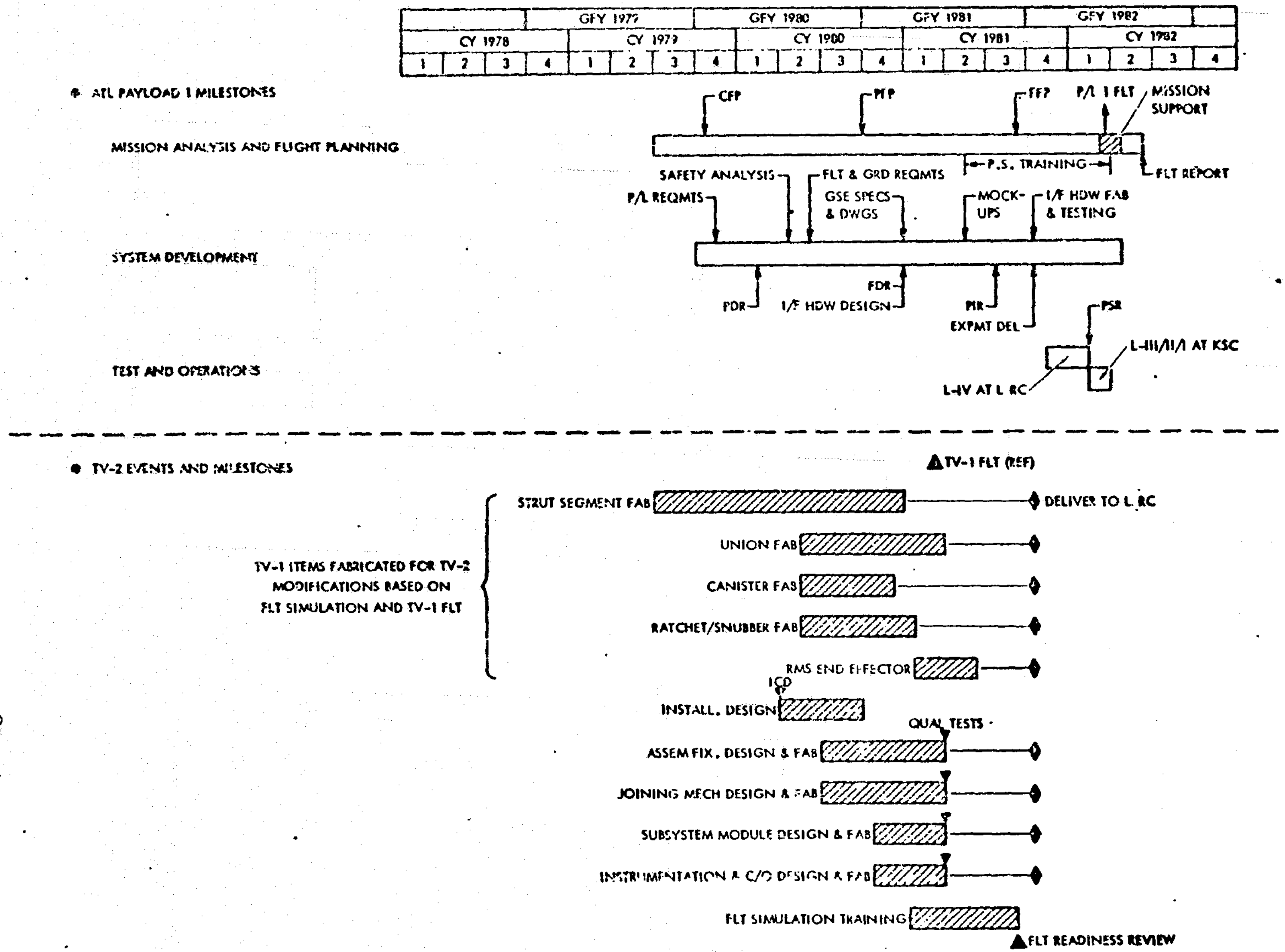



Figure A-5. TV-2 Development Schedule

possibly 250 $m^2$ to give a long operational life expectancy (e.g., 10 years). The on-orbit operations for the Educational TV satellite would then consist in deployment of the satellite and orbit transfer propulsion module from the Orbiter, performing satellite and propulsion subsystems checkout as required and then monitoring the system ascent to the operational orbit. The solar array deployment would be accomplished at GEO in order to allow relatively high T/W ratio transfer propulsion (e.g., 1.0) for the assembly.



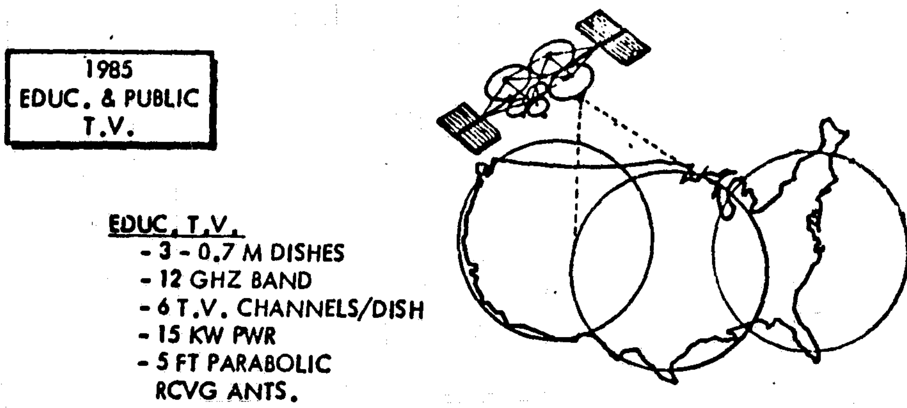



Figure A-6. Educational TV System Concept

The Educational TV satellite has the earliest scheduled operational date (1985) of the Scenario A candidates. Although not selected as one of the three representative missions for the ATLASS Program Requirements study, the future large area space structures requirements should address the earlier missions as well as the three selected mission cases. Therefore, many of the technology requirements "need" dates will be governed by the mission schedules. Some of the "needs" required to support this, as well as later large space structures satellite designs, would then include modeling and scaling laws, ground test and validation facilities, and Orbiter assembly aids and operations.

National Information System Summary

Figure A-7 shows the National Information System satellite concept presented in Scenario A. The operational orbit for this system would be at geosynchronous altitude. This satellite would be assembled from the Orbiter base in a 28.5-degree low earth orbit and then would be transferred by a low thrust-to-weight (mass) ratio (e.g., T/W = 0.1) to the operational location.

It will be noted from the figure that this concept requires three 23-m-diameter antennas. This size unit will then require deployable or erectable designs to allow packaging in the Orbiter bay. The satellite assembly is envisioned as consisting of the following steps:

1. Structure and payload delivered to the assembly orbit in one Orbiter flight.

2. Satellite structural framework erected on orbit using Orbiter construction aids.

3. Deployable antennas removed from cargo bay, deployed to operational configuration, and attached to support framework using Orbiter construction aids and EVA as required.

4. Installation and wiring of solar array panels and power/signal distribution as required.

5. Completion of other satellite subsystems installations.

6. Attachment of orbit-to-orbit transfer propulsion stage to the satellite.

7. Checkout of all satellite and propulsion unit systems.

8. Transfer of satellite to the GEO operational orbit.

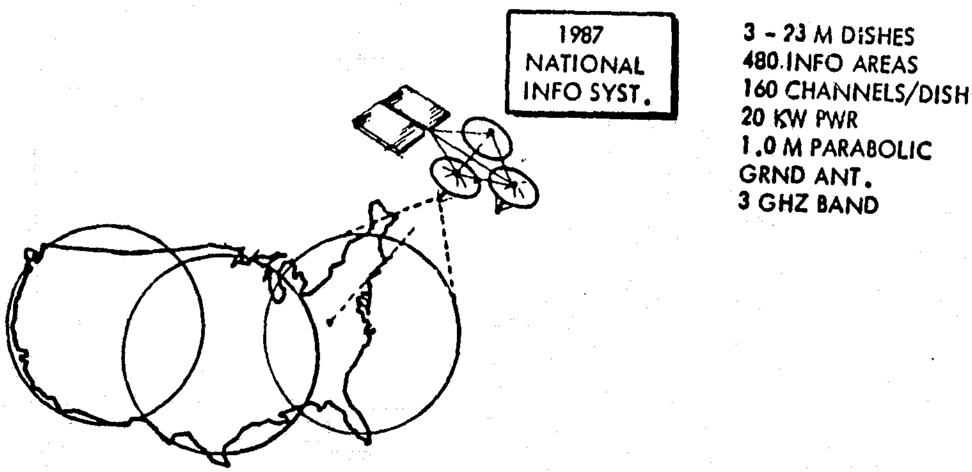



Figure A-7. National Information System Concept

The satellite electronic and power distribution systems should be prewired and attached to the major components (e.g., antennas, structure) to the extent feasible. The assumed 25-m spacing of the three antennas will result in the requirement of an approximately 25-m×25-m square platform with the antennas mounted on three corners and the approximately 330-$m^2$ solar array mounted on the fourth corner. The operational configuration overall diameter will then be approximately 60 meters.

The deployed antennas and solar arrays of lightweight design would limit acceleration loads which can be tolerated during transfer to operational orbit. A design tradeoff to be considered would be to keep the solar array and antennas in the folded condition with automatic deployment at the satellite destination. This could allow higher T/W for the transfer operations.

Because of the increased size of this communication system relative to the preceding case, additional technology needs would be required to support

the listed operational date of 1987. These could include technology requirements subjects such as (1) 20- to 30-meter Multibeam Reflector, (2) 50- to 100-meter Erectable Structures, (3) Large Platform Attitude Control, and (4) Low-Thrust Orbit Transfer.

Electronic Mail Satellite Summary

The Scenario A concept for an electronic mail satellite is illustrated in Figure A-8. This concept was selected as one of the representative missions for the current ATLASS Program Requirements study. Other detailed characteristics of the configuration are indicated on the briefing chart (page 17). The figures show a requirement for six 23-m deployable antennas, a power requirement of 60-70 kW, a solar array of up to 860 $m^2$, and a satellite mass to be delivered to GEO of almost 25,000 kg (including RCS fuel).



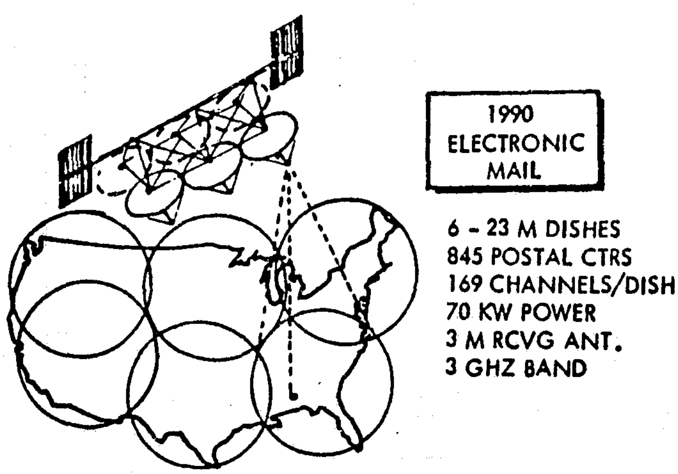



Figure A-8. Electronic Mail Satellite Concept

The structural platform is depicted as a tetrahedral erectable platform with strut elements approximately 12 meters long. The deployed satellite results in an approximate planform of 70×100 m maximum dimensions. The general concept of the satellite assembly would be similar to that of the previous case. First would come on-orbit assembly of the structural platform, and then installation of the six deployable antennas and the other supporting subsystems for the satellite. The low-thrust orbital transfer propulsion system would then be attached to the satellite and the entire assembly checked for operational readiness. Transfer to operational orbit would then be accomplished. Because of the estimated large mass of the electronic mail satellite, two or more Orbiter deliveries may be required for the assembly and upper-stage systems.

The previously referenced *Extended Manned Space Activities Status Report, PD 77-20*, compared both Orbiter based and a separate construction facility based operations for the satellite. The conclusion reached was that for the "Scenario A" type of large space structures missions and number of launches,

it would not be economically efficient to develop the construction facility. Therefore, the Orbiter-based construction of the Electronic Mail Satellite was recommended.

It may be noted that more design tradeoff studies for the Electronic Mail Satellite will be required before the final system requirements can be established. Antenna sizes can be reduced if higher power levels are utilized. The availability of communication bandwidths required in the proposed 3-GHz frequency range for the proposed 1990 operational time period also needs further investigation. Any necessary changes in communications frequency assignments also can impact system design.

The Electronic Mail Satellite again presented growing requirements in several technology areas in comparison to the two earlier scheduled communication systems of the prospective mission scenario. New technology areas which may become critical for this applicat-on include (1) integrated power and signal distribution, (2) central command/control/switching, and (3) multipaction/EMI suppression. Platform figure measurement also may be needed as the supporting platform areas are increased and multiple antenna installations are specified.

Radar Surveillance Satellite Summary

Figure A-9 illustrates the concept and major system design considerations for the Radar Surveillance Satellite, chosen as the sixth entry for the prospective mission scenario (Figure A-2). This concept presents the most demanding requirements in terms of size and new technologies of all the missions considered in the present study. It was selected as one of the three representative missions on which to base the ATLASS program requirements.

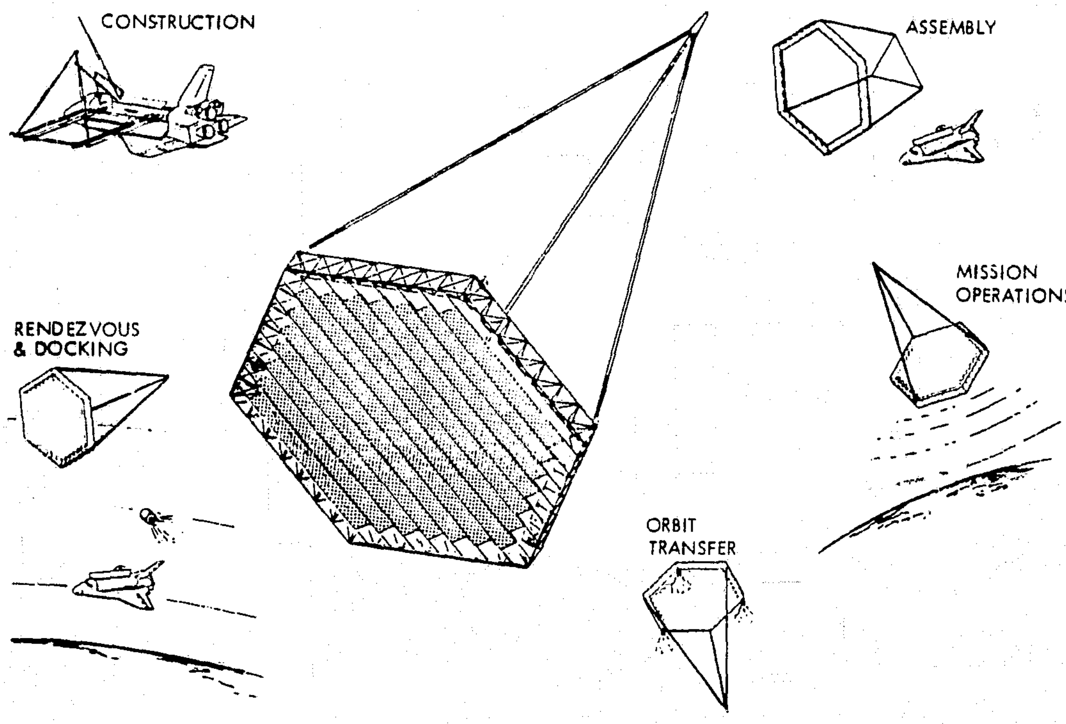



Figure A-9. Radar Surveillance Satellite Concept

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Figure A-10 provides a display of some of the basic structural items, subassemblies, and major dimensions of the compression frame assembly and the tripod mast concept. three candidate structural concepts for the mast are shown at the bottom of the figure. The apex of the mast holds the radar feed electronics and the proposed electrical power system (nuclear).

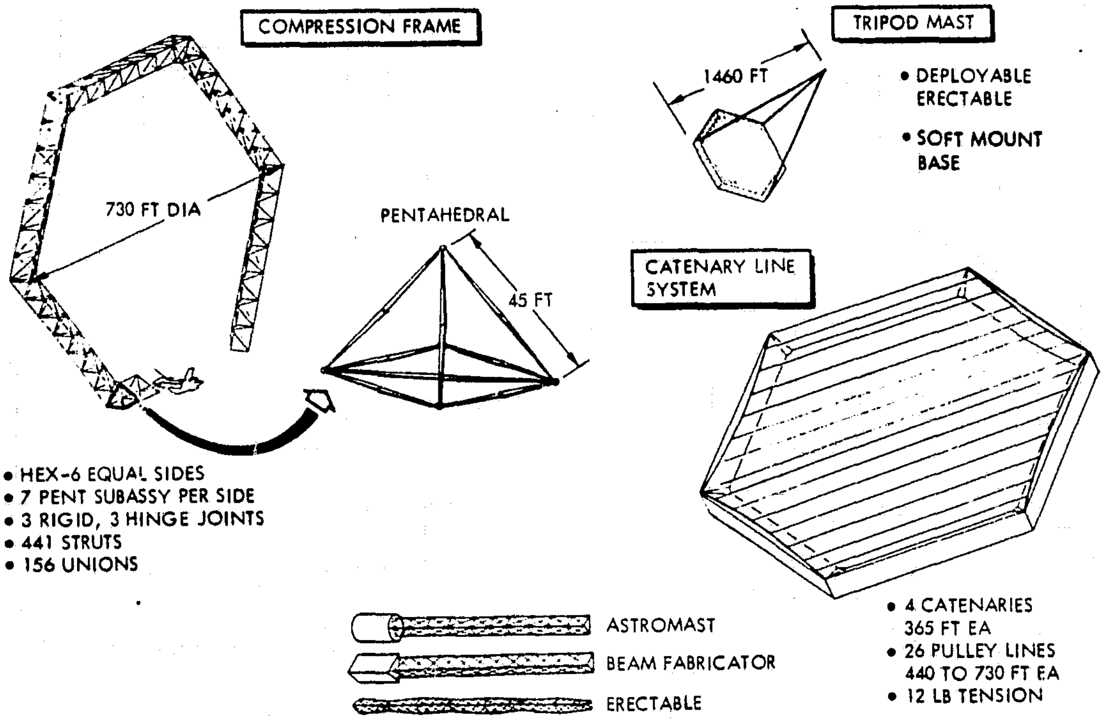



Figure A-10. Radar Structural Concept Details

Figure A-11 illustrates various steps in the frame construction, mast deployment, and sensor blanket installation. The illustrations are obtained from the Rockwell International Space Division proposal study prepared for submittal to the Air Force. This, or equivalent concepts, will receive further study in the near future.

This requirement for the equivalent 180-m-diameter lens-type microwave radar provides an example of large area space structures of prime interest for application outside the NASA mission models. A total of three Orbiter launches is anticipated as a requirement to deliver the radar lightweight structure and payload plus the chemical low-thrust propulsion units to the assembly orbit. Some additional details of the concept are shown in the "briefing" section of the report (pages 20, 21).

The unique structures design and electronic systems for the proposed surveillance radar require development in other technologies in addition to those mentioned in the communications examples; these include (1) RF Pattern Prediction, (2) 100- to 300-m Deployable Phased Array, (3) 100- to 600-m Deployable Masts, (4) Long-Life Dimensionally Stable Composites, and (5) Long-Life Polymer Film. The Multipaction/EMI Suppression and Low-Thrust Orbit Transfer Propulsion technologies also may be added difficulty for the radar concept application.

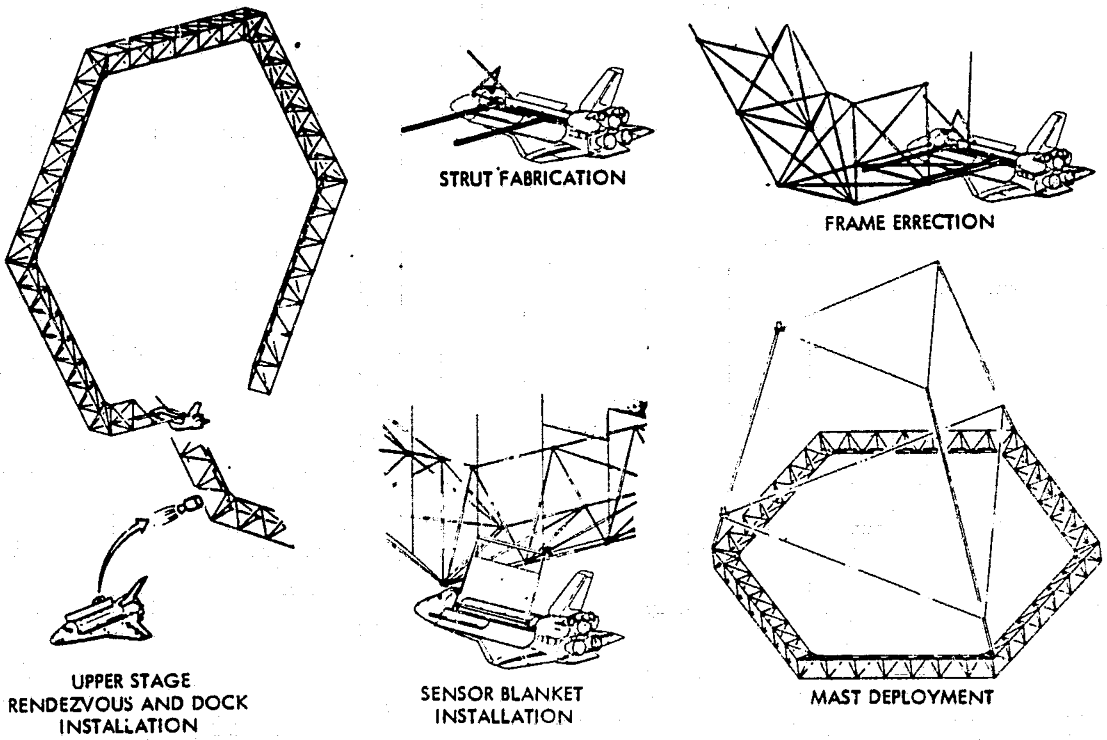
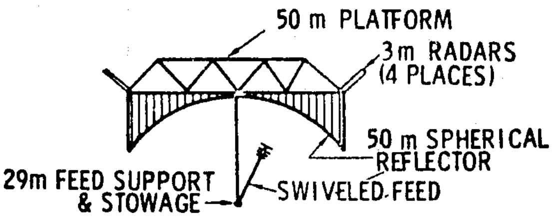



Figure A-11. Radar Construction Process Details

Radiometer/Radar Satellite Summary

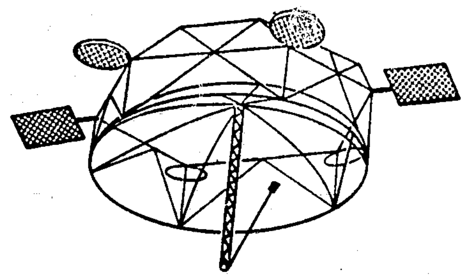
Figure A-12 depicts the 50-m-diameter multifrequency radiometer/radar combination chosen to represent the first of the large radiometer missions listed in the Scenario A group of advanced manned (or man-in-orbit supported) missions. This was also chosen as one of the three representative missions for the ATLASS scenario. In this example, both the radiometer and the four 3-m radars operate at multifrequencies ranging from 1.4 to 120 GHz. The radiometer reflector would be suspended from a structural platform and the surface contour controlled by actuators located on the structure. At the higher operating frequencies, active figure control may be required to maintain desired radiometer contour.

The need for high-resolution data requires the satellite to operate at a relatively low altitude (e.g., 740 km), and the desire for a wide band of earth surface latitude coverage requires a relatively high inclination orbit such as the 55 degrees shown on the figure. Some of the measurements are best accomplished passively with the microwave radiometer, while others require an active radar system. The proposed radars have relatively low power requirements (e.g., less than 1 kW each), and the passive radiometer sensor also has low power requirements. However, the spherical reflector radiometer requires a mechanically actuated feed system which positions the feed devices to provide up to 850-km wide earth surface scanning without moving the total structure. A power allowance of up to 5 kW was made with an estimated 100-m$^2$ solar array plus batteries proposed as a power source.




| RADAR | |
|---|---|
| FREQUENCY, GHz | MEASUREMENTS |
| 1.5 | OCEAN WAVES; SHIPS |
| 9-10 | MELTING HEIGHT; SHIPS |
| 13 | SURFACE WINDS |
| 18-22 | WATER CONTENT; VAPOR PROFILE |
| 52-60 | SURFACE PRESSURE; RAIN RATE |
| 110-120 | $H_2O$ PROFILE; RAIN RATE |

| MICROWAVE REFLECTOR | | | |
|---|---|---|---|
| FEED | FREQ GHz | BW DG. | MEASUREMENTS |
| 1 | 1.43 | .37 | OCEAN SALINITY; RMS WAVES |
| 2 | 2.64 | .24 | OCEAN SURFACE TEMP |
| 3 | 9-10 | .16 | ICE DISTRIBUTION |
| 4 | 18-20 | .11 | LIQUID WATER CONTENT |
| 5 | 52-60 | .044 | ATMOS. TEMP PROFILE; WIND |
| 6 | 110-120 | .023 | ATMOS. TEMP PROFILE |





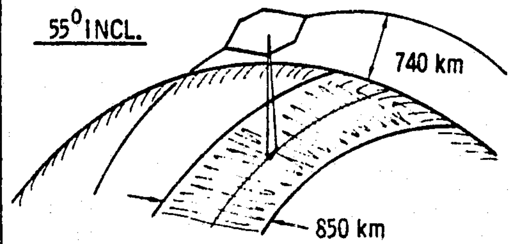



Figure A-12 Radiometer/Radar Satellite Concept

The data measurements from this earth surveillance satellite would allow synoptic weather prediction and oceanographic monitoring. Typical measurements are listed in the figure. The data also would be useful for sea shipping traffic, fishing fleets (tracking of fish migration), and pollution monitoring (oil spills, etc.).

Added technology developments for which this mission becomes a driving requirement capability include (1) Attitude Control of Flexible Systems, (2) 500- to 100-m Scanning Deployable Reflector System, and (3) Figure Measurement and Control.

Personal Communication Satellite Summary

Figure A-13 illustrates a concept for a personal communications system satellite for the mid-1990's. This represents an ambitious design which will service the entire area of the 48 contiguous states and provide for up to 1.25 million simultaneous conversations. The concept provides for a large, complex electronic facility at geosynchronous orbit in order to allow the smaller and simpler ground transmitter and receiver units required for a practical personal communications concept.

The design proposed would consist of nine 26-m-diameter antennas, together with two large solar array units, mounted on a space-erected structure. The large power estimate would result in solar array requirements in the order of 10,000 m$^2$ total area. The total planform size for this communication application could then be on the order of 80×20 m in the fully deployed configuration.

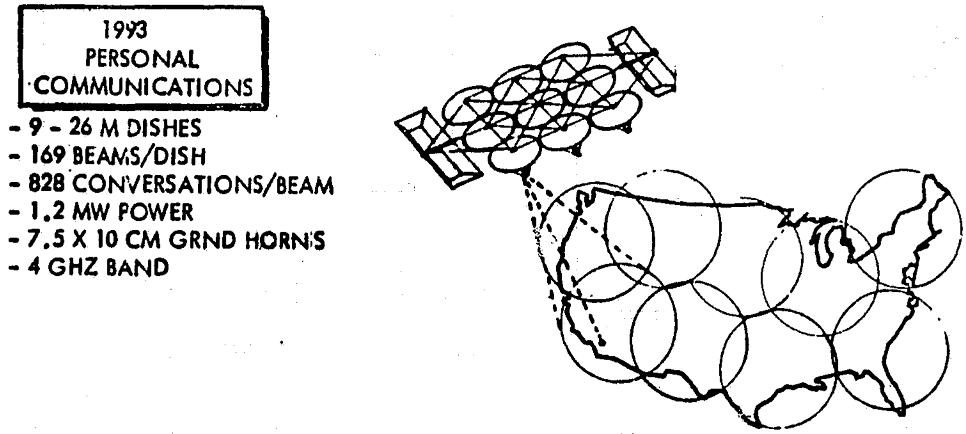



Figure A-13. Personal Communications Satellite Concept

It should be noted that many on-orbit design configurations for the personal communications systems are being studied. Major system tradeoffs need to be made involving antenna sizes, data compaction, earth surface area coverage, traffic volume assumptions, communication frequencies, and other parameters. Differing assumptions in these parameters and requirements can result in widely varying design concepts, some of which may appreciably reduce the on-orbit power levels and antenna size requirements.

# APPENDIX B

## TECHNOLOGY REQUIREMENTS VS. ATLASS TASKS MATRIX

The prospective missions (discussed in Appendix A) can be represented by the following three different classes of mission operations:

- Communications
- Microwave Radiometer
- Radar Surveillance

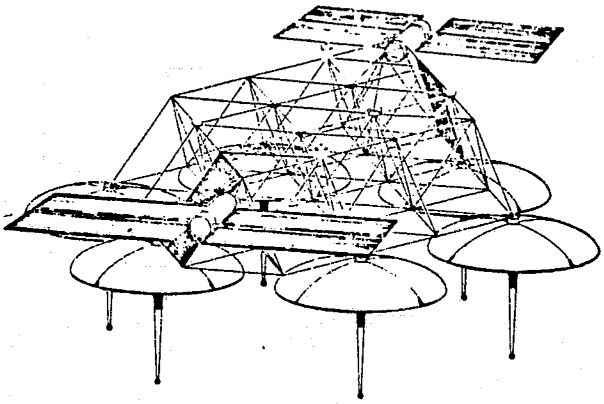
There are several distinct communication systems suggested by the mission scenario, ranging from the smallest Education and Public TV mission to the largest system used for the Personal Communication mission. It was believed that the Electronic Mail concept would best typify the overall class of communication systems.

Each of the three representative classes has been studied in sufficient depth to isolate the major areas of technology concern and development required for each concept. With an estimate of the first operational launch date for the particular class of mission, and with an understanding of the magnitude of the design and development schedule involved, it is possible to estimate when the specific technologies have to be developed and available for the various designs. Figures B-1 through B-3 show the technology areas for each mission class and the latest schedule date when the technology must be available. It is recognized that some of the technology requirements are common to more than one class of mission concepts. Therefore, the technology requirements for the individual classes have been reduced to a set of 20 different and distinct requirements, and their earliest schedule dates are shown in Table B-1 together with which class of mission gave rise to the earliest need date.

In order to resolve these technology requirements, there must be a well prepared technology development plan. The NASA Office for *Advanced Technology for Large Area Space Systems (ATLASS)* has proposed a series of technology development tasks relating to large space structures. It is recognized that the 20 technology requirements identified can be resolved by investigations in one or more of the subtasks in the proposed ATLASS plan.

Each of the technology requirements was compared to the current state of the art for that particular technology, and a rank ordering established for the degree of technology advancement. The rank ordering was defined as a development factor ranging from 1 (existing, needing slight modification) to 4 (substantially beyond state of the art). Detail definitions of these development factors are given in Table B-2.

A panel of Rockwell International specialists reviewed the 20 technology requirements pertinent to the mission scenario, and determined which of the



OPERATIONAL DATE
1990

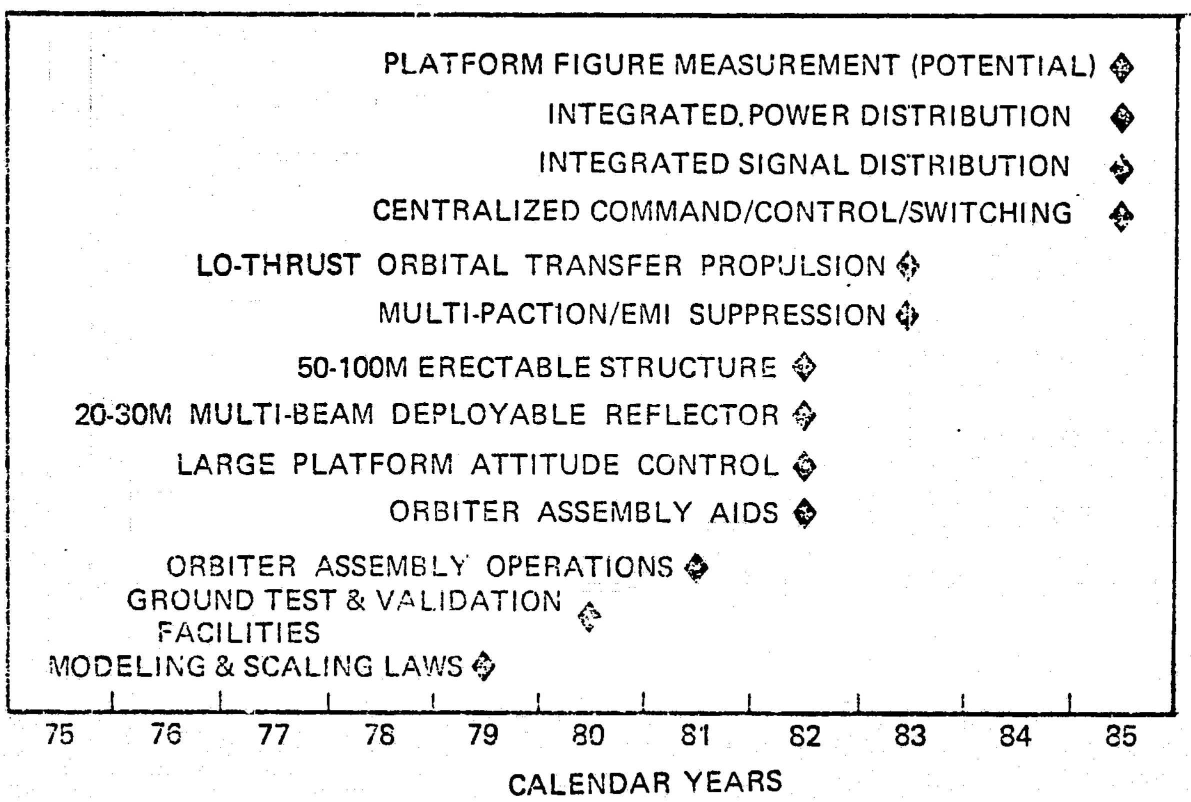
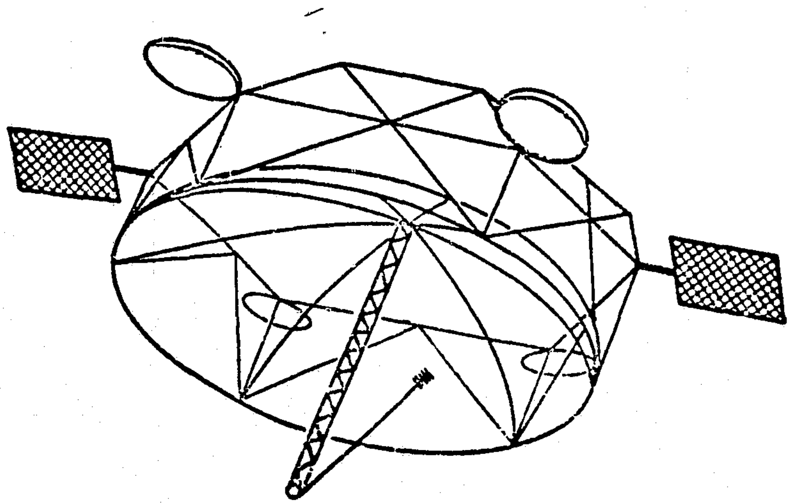



Figure B-1. Technology Schedule for Communications (Electronic Mail)



OPERATIONAL DATE
1990



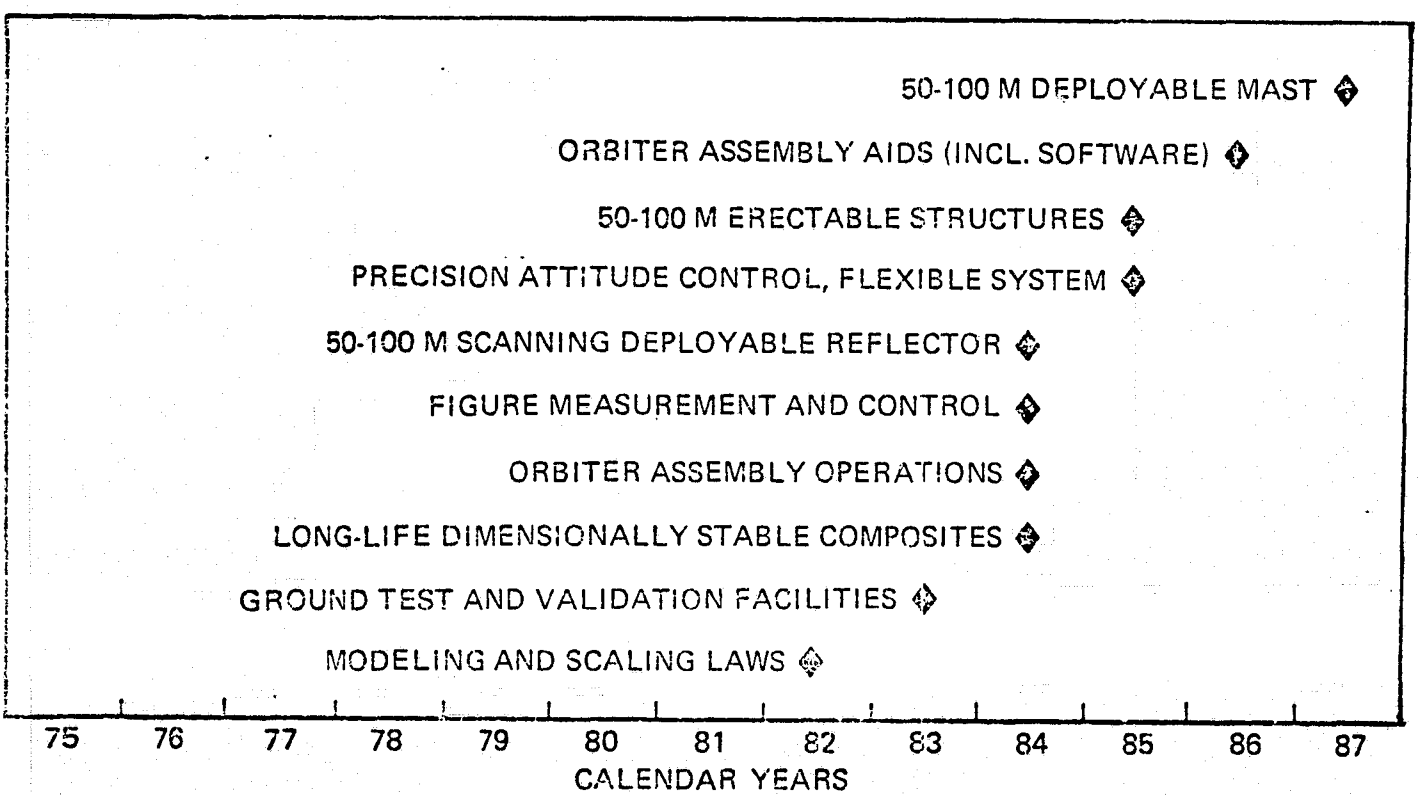



Figure B-2. Technology Schedule for Radiometer

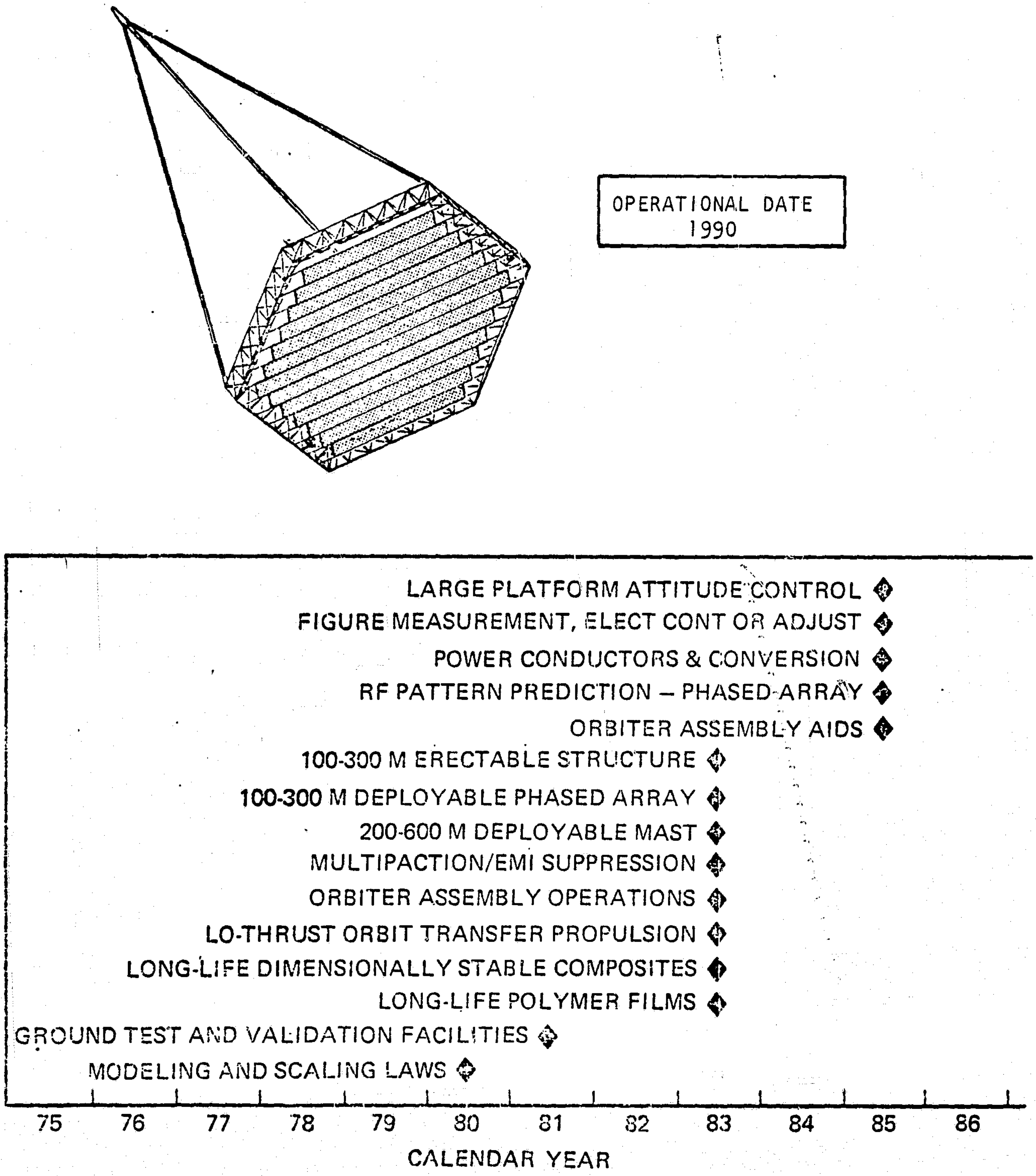



Figure B-3. Technology Schedule for Radar Surveillance

Table B-1. Technology Requirements

| | 80 | 81 | 82 | 83 | 84 | 85 |
|---|---|---|---|---|---|---|
| ATTITUDE CONTROL OF FLEXIBLE SYSTEM/RADIOMETRY | | | | | | X |
| INTEGRATED POWER DISTRIBUTION/COMMUNICATION | | | | | | X |
| INTEGRATED SIGNAL DISTRIBUTION/COMMUNICATION | | | | | | X |
| CENTRAL COMMAND/CONTROL/SWITCHING/COMMUNICATION | | | | | | X |
| RF PATTERN PREDICTION/PHASED ARRAY RADAR | | | | | | X |
| 50-100 M SCANNING DEPLOYABLE REFLECTOR STRUCT/RADIOM | | | | | X | |
| FIGURE MEASUREMENT AND CONTROL/RADIOMETRY | | | | | X | |
| 100-300 M DEPLOYABLE PHASED ARRAY/SURVEILLANCE RADAR | | | | X | | |
| 100-600 M DEPLOYABLE MAST/RADAR | | | | X | | |
| MULTIPACTION/EMI SUPPRESSION/COMMUNICATION/RADAR | | | | X | | |
| LO-THRUST ORBIT TRANSFER PROPULSION/COMMUNICATIONS/RADAR | | | | X | | |
| LONG-LIFE DIMENSIONALLY STABLE COMPOSITES/RADAR | | | | X | | |
| LONG-LIFE POLYMER FILMS/RADAR | | | | X | | |
| 50-100 M ERECTABLE STRUCTURES/COMMUNICATIONS | | | X | | | |
| 20-30 M MULTI-BEAM DEPLOYABLE REFLECTOR STRUCT/COMM | | | X | | | |
| LARGE PLATFORM ATTITUDE CONTROL/COMMUNICATION | | | X | | | |
| ORBITER ASSEMBLY AIDS/COMMUNICATIONS | | | X | | | |
| ORBITER ASSEMBLY OPERATIONS/COMMUNICATIONS | | X | | | | |
| GROUND TEST AND VALIDATION FACILITIES/COMMUNICATIONS | | X | | | | |
| MODELING AND SCALING LAWS/COMMUNICATIONS | X | | | | | |

CALENDAR YEARS

Table B-2. Status of Technology Development

| Tech. Dev. Factor | Definition |
|---|---|
| 1 | State of the art--existing comparable items of hardware, methods of analysis, and standard ground testing procedures--space qualified. At most, needing slight modification to existing design and test practices. |
| 2 | Slight advancement in the state of the art for the design concept, improvements in the methods of analysis, and modern advanced manufacturing and fabrication procedures. Integration and adaptation of advanced ground testing to routine application for adequate validation of concepts and components. |
| 3 | Current concepts are at best only in the laboratory state of technology development, adoption of advanced limited small-scale manufacturing processes. Ground testing requiring large-scale facilities, complex space simulation, and subsequent space testing verification. |
| 4 | Substantially beyond the current state of the art requiring major development work in fabrication, methods of analysis, tests of ground testing with simulated space environment; requires mandatory space testing for credible technology validation and space qualification. |

individual ATLASS subtasks addressed major segments of which technology requirement. The development factor weighting described in Table 2 was applied to each ATLASS technology task to indicate the degree of advancement which specific technology tasks would contribute toward the development of a technology requirement. Table B-3 is the resulting development degree matrix which considered the ATLASS task areas (Areas B through H, inclusive). These development factors will supply an indication of the significance of the individual tasks. For example, Task B2 (Controls Analysis for Large Surfaces/Platforms) has development factors ranging from 2 to 4. The most significant task is the *development of synthesis techniques of control laws and structural characterization for maximum performance*, which will resolve the technology requirements associated with *Figure Measurement and Control*, a main technology driver of the large-diameter radiometers.

It will be noted that the *Cable and Line Deployment, Surveillance Radar* technology area of Table B-3 has been replaced by the *Long-Life Polymer Films* technology in Table B-1 and in the briefing summary report. This Polymer Films technology will then represent a combination of the Cable and Line Deployment technology and *Long-Life Dimensionally Stable Composites* of the analyses in Table B-3.

A summary of the maximum technology advancements achieved by the ATLASS tasks is shown in Table B-4, which indicates there are five important tasks with a technology development factor of 4; these being in the area of controls,

## Table B-3. Technology Requirement/ATLASS Task Matrix



| ATLASS PROPOSED TECHNICAL PROGRAM PLAN | 50-100m ERECTABLE STRUCTURE/COMM | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOM. | 100-300m DEPLOYABLE PHASED ARRAY/SURV RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM | MULTIPACTION/EMI SUPPRESSION/SURV RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B.1 ELECTROMAGNETIC ANALYSIS FOR LARGE REFLECTORS/ARRAYS** | | | | | | | | | | | | | | 3 | | | | | | 3 |
| **TASKS:** a. DEVELOP A COST EFFECTIVE LARGE REFLECTOR ELECTROMAGNETIC (EM) FIELD PREDICTION ANALYSIS FOR SCANNING AND MULTIBEAM CONTINUOUS-SURFACE REFLECTOR ANTENNAS | | | | | | | | | | | | | | 3 | | | | | | 3 |
| b. DEVELOP AN EM FIELD PREDICTION ANALYSIS FOR LARGE SEGMENTED REFLECTORS | | | | | | | | | | | | | | 3 | | | | | | 3 |
| c. DEVELOP EM ANALYSIS FOR VERY LARGE PHASED ARRAYS | | | | | | | | | | | | | | 3 | | | | | | 3 |
| d. DEVELOP ANALYSIS INCORPORATING FIGURE MEASUREMENT TECHNIQUES FOR EM EVALUATION OF REFLECTORS AND PHASED ARRAYS | | | | | | | | | | | | | | 3 | | | | | | 3 |
| **B.2. CONTROLS ANALYSIS FOR LARGE SURFACES/PLATFORMS** | | | | | | 2 | 3 | | 4 | | | | | | | | 2 | | | |
| **TASKS:** a. DEVELOP PERFORMANCE CRITERIA FOR USE IN EVALUATION AND DESIGN OF CONTROL SYSTEMS (POINTING, ATTITUDE, AND SHAPE) | | | | | | 2 | 2 | | 2 | | | | | | | | 2 | | | |
| b. DEVELOP ANALYSIS TECHNIQUES FOR MAXIMUM PERFORMANCE THROUGH PLACEMENT OF SENSORS AND ACTUATORS | | | | | | 2 | 2 | | 3 | | | | | | | | - | | | |
| c. DEVELOP SYNTHESIS TECHNIQUES OF CONTROL LAWS AND STRUCTURAL CHARACTERIZATION FOR MAXIMUM PERFORMANCE | | | | | | 2 | 3 | | 4 | | | | | | | | 2 | | | |
| **B.3. STRUCTURAL LOADS/DISTORTION/THERMAL ANALYSIS FOR LARGE SURFACES/PLATFORMS** | 2 | 2 | 3 | 3 | 2 | | | 3 | | | | | | | | | | | | |
| **TASKS:** a. DEFINE EXTERNAL/INTERNAL LOAD MODELING TECHNIQUES | 2 | 2 | 2 | 3 | 2 | | | 3 | | | | | | | | | | | | |
| b. DEVELOP SPECIAL PURPOSE STRUCTURAL ANALYSIS TECHNIQUES | 2 | 2 | 2 | 3 | 2 | | | 2 | | | | | | | | | | | | |
| c. DEVELOP SIMPLIFIED TEMPERATURE PREDICTION METHOD | 2 | 2 | 2 | 2 | 2 | | | 2 | | | | | | | | | | | | |
| d. DEVELOP METHOD OF ANALYZING THERMAL DISTORTIONS AND STRESSES, JOINT FLEXIBILITY, AND IMPERFECTIONS | 2 | 2 | 3 | 2 | 2 | | | 2 | | | | | | | | | | | | |
| e. EVALUATE AND REFINE MODELS FOR DYNAMIC RESPONSE | 2 | 2 | 2 | 3 | 2 | | | 2 | | | | | | | | | | | | |

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Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)





ATLASS PROPOSED TECHNOLOGY PROGRAM PLAN

| ATLASS PROPOSED TECHNOLOGY PROGRAM PLAN | 50-100m ERECTABLE STRUCTURE/COMM | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV RADAR | ~100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV. RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B.4. STRUCTURAL DYNAMICS** | | | 3 | | | 3 | 3 | | 3 | | | | | | | 2 | | | | 3 |
| **TASKS:** a. DEVELOP STRUCTURAL IDEALIZATION CRITERIA CORRELATED WITH LEVEL OF ACCURACY. | | | 2 | | | | 2 | | 2 | | | | | | | | | | | 2 |
| b. DEVELOP ACCURATE AND EFFICIENT MODELING APPROACHES THAT WILL MEET ACCURACY REQUIREMENTS. | | | 3 | | | 2 | 2 | | 3 | | | | | | | 2 | | | | 3 |
| c. DEVELOP AN OPTIMIZED ANALYSIS/TEST APPROACH FOR GENERATION AND VERIFICATION OF STRUCTURAL DYNAMIC CHARACTERISTICS | | | 2 | | | 3 | 3 | | 3 | | | | | | | 2 | | | | |
| d. DEVELOP EFFECTIVE AND EFFICIENT DYNAMIC RESPONSE CALCULATION PROCEDURES (LOADS) FOR ASSEMBLY, DOCKING, MANEUVERS, AND CONTROL-INDUCED RESPONSES. | | | | | | 2 | 3 | | 3 | | | | | | | 2 | | | | |
| e. DEVELOP PROCEDURES AND TECHNIQUES TO MINIMIZE RESPONSES | | | 2 | | | | | | | | | | | | | 2 | | | | |
| **B.5. INTEGRATED DESIGN DEVELOPMENT** | 2 | 2 | 3 | 2 | | 2 | 3 | 2 | | | | | | 3 | | | 2 | | | |
| **TASKS:** a. DEVELOP OPTIMIZATION TOOLS | 2 | | 3 | | | | | | | | | | | | | | | | | |
| b. INTEGRATE FIRST LEVEL LOADS AND STRUCTURE CAPABILITY | 2 | 2 | 2 | 2 | | | | 2 | | | | | | | | | | | | |
| c. ADD ACTIVE CONTROLS/COUPLING | | | | | | 2 | 3 | | | | | | | | | | 2 | | | |
| d. ADD ELECTRONIC PERFORMANCE PREDICTION CAPABILITY AND UPGRADE LOADS, STRUCTURE, CONTROLS | | | | | | | | | | | | | | 3 | | | | | | |
| e. EXERCISE AND EVALUATE SYSTEM | | | | | | | | | | | | | | | | | | | | |
| f. REFINE COMPONENT CODES | | | | | | | | | | | | | | | | | | | | |

Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

SHEET 3 OF 10

| | | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/ RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/ RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM. | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **C.1. CONCEPT DEVELOPMENT** | | 2 | | | | | | | | | | | | | | | 1 | | | | |
| **TASKS:** | DEVELOP TRADEOFF AND EVALUATION CRITERIA TO PERMIT SELECTION OF STRUCTURAL CONFIGURATIONS, BASIC ELEMENTS, UNION/JOINTS, ASSEMBLY TECHNIQUES, AND SUB-STRUCTURES FOR MINIMUM COST, MINIMUM RISK, AND MAXIMUM VERSATILITY. | 2 | | | | | | | | | | | | | | | 1 | | | | |
| **C.2 BASIC ELEMENTS** | | 2 | | | | | | | | | | | | | | | | | | 2 | |
| **TASKS:** | a. IDENTIFY THROUGH BOTH INHOUSE AND CONTRACTUAL EFFORTS CONCEPTUAL BASIC ELEMENT DESIGNS FOR ERECTABLE SPACE STRUCTURES. | 1 | | | | | | | | | | | | | | | | | | | |
| | b. DEVELOP ANALYSES TO PREDICT THE BEHAVIOR OF THE CONCEPTS. | 1 | | | | | | | | | | | | | | | | | | | |
| | c. PERFORM ALL TESTS NECESSARY FOR EVALUATION OF THE BASIC ELEMENT AND VERIFICATION OF THE ANALYSES. | 2 | | | | | | | | | | | | | | | | | | 2 | |
| **C.3 ERECTABLE UNIONS/JOINTS** | | 2 | | | | | | | | | | | | | | | 2 | | | 1 | |
| **TASKS:** | a. IDENTIY THROUGH BOTH INHOUSE AND CONTRACTUAL EFFORT CANDIDATE UNION/JOINTS AND JOINING PROCEDURES NEEDED TO ASSEMBLE THE CANDIDATE BASIC ELEMENTS INTO STRUCTURAL SYSTEMS. | 1 | | | | | | | | | | | | | | | 1 | | | | |
| | b. DEFINE CRITERIA FOR DESIGN OF ASSEMBLY PROCEDURES BASED ON AVAILABLE UNION/JOINT CONCEPTS. | 2 | | | | | | | | | | | | | | | 2 | | | | |
| | c. PERFORM ALL TESTS NECESSARY FOR THE EVALUATION AND VERIFICATION OF THE STRUCTURAL PERFORMANCE, INTEGRITY AND ANALYTICAL REPRESENTATION OF THE CANDIDATE UNIONS/JOINTS. | | | | | | | | | | | | | | | | 1 | | | 1 | |

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Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

SHEET 4 OF 10

ATLASS PROPOSED TECHNICAL PROGRAM PLAN

| ATLASS PROPOSED TECHNICAL PROGRAM PLAN | 50-100m ERECTABLE STRUCTURE/COMM | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE RE-FLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV/RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM. | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **C.4 MULTI-ELEMENT MODULE TEST** | 2 | | | | | | | | | | | | | | | | 2 | | 3 | 2 |
| **TASKS:** a. DEFINE THE CONFIGURATION OF THE MULTI-ELEMENT ASSEMBLY NEEDED FOR EFFECTIVE EVALUATION CONCEPTS AND VERIFICATION OF ANALYSES. | 2 | | | | | | | 1 | | | | | | | | | | | | |
| B. DEVELOP THE NEW EXPERIMENTAL TECHNIQUES AND TEST EQUIPMENT NEEDED FOR GROUND TESTS. | | | | | | | | | | | | | | | | | 2 | | 3 | |
| c. PERFORM NECESSARY EVALUATION TESTS. | | | | | | | | | | | | | | | | | 2 | | 2 | 2 |
| d. PROVIDE DATA NEEDED TO VERIFY ALL ANALYTICAL METHODS FOR ANALYSES OF ASSEMBLED ERECTABLE STRUCTURES. | 2 | | | | | | | | | | | | | | | | 2 | | 2 | 2 |
| **C.5 ASSEMBLY TECHNIQUES** | | | | | | | | | | | | | | | 3 | 4 | | | | |
| **TASKS:** a. IDENTIFY, THROUGH COMBINED INHOUSE AND CONTRACTUAL INVESTIGATIONS, ASSEMBLY TECHNIQUES USING EVA, MANIPULATOR, AND AUTOMATED ASSEMBLY TECHNIQUES. | | | | | | | | | | | | | | | 2 | 2 | | | | |
| b. PERFORM GROUND TESTS TO EVALUATE THE ABILITY OF THESE TECHNIQUES TO ASSEMBLE STRUCTURES USING CANDIDATE UNION/JOINTS AND BASIC ELEMENTS. | | | | | | | | | | | | | | | 3 | 4 | | | | |
| c. DEFINE A SET OF REQUIREMENTS FOR ASSEMBLY EQUIPMENT (INCLUDING JIGS AND FIXTURES). | | | | | | | | | | | | | | | 3 | 3 | | | | |
| d. DEVELOP ASSEMBLY LINE ESTIMATES. | | | | | | | | | | | | | | | | 3 | | | | |
| e. CATEGORIZE ASSEMBLY PROCEDURES | | | | | | | | | | | | | | | | 3 | | | | |
| **C.6 MAJOR GROUND TEST** | 3 | | | | | | | | | | | | | | | | | 2 | 4 | |
| **TASKS:** a. DEFINE GROUND TEST PROGRAM PHILOSOPHY AND PROCEDURES. | | | | | | | | | | | | | | | | | | | 2 | 2 |
| b. DESIGN OF TEST ARTICLE | 2 | | | | | | | | | | | | | | | | | | 2 | 4 |
| c. LOCATION AND MODIFICATION OF TEST FACILITY. | | | | | | | | | | | | | | | | | | | | 2 |
| d. CONSTRUCTION OF TEST ARTICLES | 3 | | | | | | | | | | | | | | | | | | 2 | 3 |
| e. PERFORM TESTS | | | | | | | | | | | | | | | | | | | 2 | 4 |
| f. EVALUATE TEST DATA | | | | | | | | | | | | | | | | | | | 2 | 3 |

Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)



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| ATLASS PROPOSED TECHNICAL PROGRAM PLAN | | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM RADIOMETER | 100-300m DEPLOYABLE REFLECTOR/ RADAR | 50-100m SCANNING RADIOMETER DEPLOYABLE PHASED ARRAY/SURV. | CABLE & LINE DEPLOYABLE REFLECTOR/ | LARGE PLATFORM ATTITUDE CONTROL/SURV. RADAR | PRECISION ATTITUDE CONTROL/COMM | 100-600m DEPLOYABLE MAST/RADIOMETER | FIGURE MEASUREMENT & CONTROL/SURV. RADAR | POWER DISTRIBUTION/CONTROL/RADIOMETER | SIGNAL DISTRIBUTION/COMM | CENTRAL COMMAND/CONTROL/COMM/RADAR | MULTIPACTION/EMI SUPPRESSION/SWITCHING/COMM. | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM. | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **D.1 CONCEPT DEVELOPMENT** | | | | 3 | | | | | 2 | | | | | | | | | | | | 2 |
| **TASKS:** | a. IDENTIFY THROUGH IN-HOUSE & CONTRACTUAL EFFORTS CONCEPTUAL DESIGNS OF DEPLOYABLE PLATFORMS. | | | 3 | | | | | 2 | | | | | | | | | | | | |
| | b. DEVELOP ANALYSES TO PREDICT BOTH DYNAMIC BEHAVIOR & SURFACE ACCURACY. | | | 2 | | | | | 2 | | | | | | | | | | | | |
| | c. PERFORM SMALL SCALE COMPONENT TESTS FOR THE EVALUATION OF CONCEPTS & VERIFICATION OF ANALYSES. | | | 2 | | | | | 2 | | | | | | | | | | | | 2 |
| | d. PERFORM TRADEOFF STUDIES TO EVALUATE & SELECT MOST PROMISING CONCEPTS. | | | 2 | | | | | 2 | | | | | | | | | | | | 2 |
| **D.2 TEST FACILITY MODIFICATIONS** | | | | | | | | | | | | | | | | | | | | 2 | |
| **TASKS:** | a. DEFINE REQUIREMENTS FOR GROUND TESTING. | | | | | | | | | | | | | | | | | | | 2 | |
| | b. IDENTIFY CANDIDATE FACILITIES & DEFINE NEEDED MODIFICATIONS. | | | | | | | | | | | | | | | | | | | 2 | |
| | c. CONSTRUCT NECESSARY MODIFICATION. | | | | | | | | | | | | | | | | | | | 2 | |
| **D.3 MODULE DEPLOYMENT TESTS** | | | | 3 | | | | | 3 | | | | | | | | | | | 3 | |
| **TASKS:** | a. DEFINE CONFIGURATIONS, TEST PHILOSOPHY & PROCEDURES NEEDED FOR EFFECTIVE EVALUATION OF CONCEPTS & VERIFICATION OF ANALYSES FOR DEPLOYABLE PLATFORMS | | | | | | | | | | | | | | | | | | | 2 | |
| | b. DESIGN AND BUILD NECESSARY TEST STRUCTURES. | | | 2 | | | | | 2 | | | | | | | | | | | | |
| | c. PERFORM REQUIRED STATIC & DYNAMIC TESTS. | | | 3 | | | | | 3 | | | | | | | | | | | 3 | |
| | d. PROVIDE DATA NEEDED TO VERIFY ALL ANALYTICAL METHODS FOR DEPLOYABLE PLATFORMS. | | | 3 | | | | | 2 | | | | | | | | | | | 3 | |
| **D.4 ASSEMBLY OF DEPLOYED MODULES** | | | | 3 | | | | | | | | | | | | | 3 | | | 3 | |
| **TASKS:** | a. DEVELOP METHOD OF COUPLING DEPLOYED MODULES | | | 3 | | | | | | | | | | | | | 2 | | | | |
| | b. DEFINE LIMITS ON SIZE OF RELIABLE DEPLOYABLE MODULES. | | | 2 | | | | | | | | | | | | | | | | | |
| | c. VERIFY RELIABILITY OF ASSEMBLY TECHNIQUES. | | | | | | | | | | | | | | | | 3 | | | 3 | |

Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

SHEET 6 OF 10

ATLASS PROPOSED TECHNICAL PROGRAM PLAN

| | | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/ RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/ RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR. | LARGE PLATFORM ATTITUDE CONTROL/COMM. | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV. RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM. | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATIONS/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E.1 CONCEPT DEVELOPMENT | | 2 | | 3 | | | | | | | | | | | | | | | | |
| | a. IDENTIFY THROUGH IN-HOUSE AND CONTRACTUAL EFFORTS CONCEPTUAL DESIGNS OF DEPLOYABLE STRUCTURES WITH ACCURATE REFLECTOR SURFACES. | | 2 | | 3 | | | | | | | | | | | | | | | | |
| | b. DEVELOP ANALYSES TO PREDICT BOTH DYNAMIC BEHAVIOR & SURFACE ACCURACY. | | 2 | | 3 | | | | | | | | | | | | | | | | |
| | c. PERFORM SMALL SCALE COMPONENT TESTS FOR THE EVALUATION OF CONCEPTS & VERIFICATION OF ANALYSES. | | 2 | | 3 | | | | | | | | | | | | | | | | |
| | d. PERFORM TRADEOFF STUDIES TO EVALUATE & SELECT MOST PROMISING CONCEPT. | | 2 | | 2 | | | | | | | | | | | | | | | | |
| | E.2 MODULE DEPLOYMENT TESTS | | 3 | | 3 | | | | | | | | | | | | | | | 3 | |
| TASKS: | a. DEFINE CONFIGURATIONS, TEST PHILOSOPHY AND PROCEDURES FOR EFFECTIVE EVALUATION OF CONCEPTS & VERIFICATION OF ANALYSES FOR DEPLOYABLE REFLECTORS. | | 1 | | 2 | | | | | | | | | | | | | | | 2 | |
| | b. DESIGN AND BUILD NECESSARY TEST STRUCTURES. | | 2 | | 2 | | | | | | | | | | | | | | | 2 | |
| | c. PERFORM REQUIRED STATIC AND DYNAMIC TESTS. | | 3 | | 3 | | | | | | | | | | | | | | | 3 | |
| | d. PROVIDE DATA NEEDED TO VERIFY ALL ANALYTICAL METHODS FOR DEPLOYABLE REFLECTOR SURFACES. | | 2 | | 2 | | | | | | | | | | | | | | | 2 | |
| | E.3 STRUCTURAL MEASUREMENT SENSOR DESIGN | | | | 2 | | 2 | 2 | | 2 | | | | | | | | | | 2 | |
| TASKS: | a. DEFINE SURFACE & DISTANCE MEASUREMENT CONCEPTS & REQUIREMENTS. | | | | 2 | | 2 | 2 | | 2 | | | | | | | | | | | |
| | b. BREADBOARD EVALUATION OF CANDIDATE CONCEPTS & BUILD BRASS BOARD. | | | | | | 1 | 1 | | 1 | | | | | | | | | | | |
| | c. GROUND TESTS OF BRASS BOARD SYSTEMS AND PROTOTYPE DEFINITION. | | | | | | 1 | 1 | | 1 | | | | | | | | | | | |
| | E.4 SURFACE ACCURACY SENSITIVITY EVALUATION | | 2 | 2 | 3 | | 2 | 4 | | 4 | | | | | | | | | | 4 | 4 |
| TASKS: | a. DEVELOP ANALYSIS FOR PREDICTING SURFACE ACCURACY PERFORMANCE CHARACTERISTICS OF VARIOUS SURFACE ADJUSTMENT CONCEPTS. | | 2 | 2 | 3 | | 2 | 2 | | 2 | | | | | | | | | | | 3 |
| | B. DESIGN AND BUILD A SEGMENT OF A CANDIDATE DEPLOYABLE SURFACE | | 2 | 2 | 2 | | | | | | | | | | | | | | | | |
| | c. PERFORM TESTS TO MEASURE SURFACE ACCURACY UNDER EXPECTED THERMAL ENVIRONMENT. | | | | | | | | | 2 | | | | | | | | | | 2 | |
| | d. FORMULATE ANALYTICAL CHARACTERIZATION OF STRUCTURE AND PERFORM TESTS TO EVALUATE ACTIVE SHAPE CONTROL CONCEPTS. | | | | | | 2 | 4 | | 4 | | | | | | | | | | 4 | 4 |
| | e. EVALUATE PREDICTABILITY OF ANALYTICAL TECHNIQUES. | | | | | | 2 | 2 | | 3 | | | | | | | | | | 2 | 2 |

Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

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ATLASS PROPOSED TECHNICAL PROGRAM PLAN

| | | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/ SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/ SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/ COMM. | PRECISION ATTITUDE CONTROL /RADIOMETER | 100-600m DEPLOYABLE MAST/ SURV. RADAR | FIGURE MEASUREMENT & CONTROL/ RADIOMETER | POWER DISTRIBUTION/COMM. | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/ SWITCHING/COMM. | MULTIPACTION/EMI SUPPRESSION/ SURV. RADAR | RF PATTERN PREDICTION/SURV RADAR | ORBITER ASSEMBLY AIDS/COMM. | ORBITER ASSEMBLY OPERATIONS/ COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/ COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/ COMM | GROUND TEST & VALIDATION/ COMM/RADAR | MODEL & SCALING/RADIOMETER/ SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F.1 SHAPE CONTROL CONCEPTS & MECHANIZATION | | | | 2 | | | | | 3 | | | | | | | | | | 3 | 3 |
| TASKS: | a. IDENTIFY SHAPE CONTROL CONCEPTS & MECHANIZATION REQUIREMENTS. | | | | 2 | | | | | 3 | | | | | | | | | | | |
| | b. DEVELOP ANALYTICAL METHODS REQUIRED TO PERFORM TRADEOFFS & EVALUATIONS OF CANDIDATE CONCEPTS. | | | | | | | | | 2 | | | | | | | | | | | 3 |
| | c. SELECT & DEVELOP TECHNIQUES TO MEET REQUIREMENTS. | | | | | | | | | 2 | | | | | | | | | | | |
| | d. EVALUATE SELECTED CONCEPTS & MECHANIZATIONS. | | | | | | | | | 2 | | | | | | | | | | 3 | |
| | F.2 ATTITUDE CONTROL CONCEPTS & MECHANIZATION | | | | | | 3 | 3 | | 4 | | | | | | | | | | | |
| TASKS: | a. DEFINE RANGE OF REQUIREMENTS, PERFORM PARAMETERS ANALYSIS, DEVELOP TRADE-OFF & EVALUATION CRITERIA. | | | | | | 2 | 2 | | 2 | | | | | | | | | | | |
| | b. DEVELOP ANALYSIS TOOLS CAPABLE OF DEALING WITH THE REQUIRED ACCURACIES. | | | | | | 2 | 2 | | 3 | | | | | | | | | | | |
| | c. SELECT & DEVELOP CONTROL TECHNIQUES, INCLUDING CONTROL/STRUCTURE INTER-ACTION, TO MEET REQUIREMENTS. | | | | | | 3 | 3 | | 4 | | | | | | | | | | | |
| | d. EVALUATE SELECTED CONCEPTS AND MECHANIZATIONS. | | | | | | 2 | 3 | | 4 | | | | | | | | | | | |
| | F.3 ORBITAL TRANSFER & STATIONKEEPING | | | | | | | | | | | | | | | | | 3 | | | |
| TASKS: | a. ESTABLISH ORBITAL TRANSFER & STATIONKEEPING REQUIREMENTS. | | | | | | | | | | | | | | | | | 2 | | | |
| | b. DEVELOP ANALYTICAL TOOLS REQUIRED TO PERFORM TRADEOFFS & EVALUATIONS OF CANDIDATE CONCEPTS. | | | | | | | | | | | | | | | | | 2 | | | |
| | c. SELECT & DEVELOP CONTROL TECHNIQUES FOR ORBITAL TRANSFER & STATION-KEEPING. | | | | | | | | | | | | | | | | | 3 | | | |
| | d. EVALUATE SELECTED CONCEPTS & MECHANIZATIONS. | | | | | | | | | | | | | | | | | 3 | | | |
| | F.4 CONTROL SYSTEM INTEGRATION | | | | | | 3 | 3 | | | | | | | | | | | | 3 | 3 |
| TASKS: | a. DEFINE FUNCTIONAL & PRELIMINARY DESIGN REQUIREMENTS FOR CONTROL SYSTEM ELEMENTS. | | | | | | 2 | 2 | | | | | | | | | | | | | |
| | b. DEFINE CONTROL SYSTEM ELEMENT INTERFACES & EVALUATE INTERACTIONS BETWEEN STRUCTURE & CONTROL SYSTEM ELEMENTS. | | | | | | 3 | 2 | | | | | | | | | | | | | |
| | c. PERFORM TRADEOFF STUDIES FOR SELECTION OF PREFERRED CONTROL SYSTEM DESIGN CONCEPTS | | | | | | 2 | 2 | | | | | | | | | | | | | |
| | d. PERFORM SIMULATIONS AND GROUND TESTS AS NECESSARY FOR EVALUATION OF THE CONCEPTS. | | | | | | 3 | 3 | | | | | | | | | | | | 3 | 3 |

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Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

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ATLASS PROPOSED TECHNICAL PROGRAM PLAN

| ATLASS PROPOSED TECHNICAL PROGRAM PLAN | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV. RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM. | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATION/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP./COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **G.1 SIGNAL CONDITIONING DATA ACQUISITION, AND TRANSFER TECHNIQUES** | | | | | | | | | | 2 | 2 | 2 | | | | | | | | |
| **TASKS:** a. DETERMINE & DEVELOP INTER-ELEMENT DISTRIBUTION SYSTEMS & METHODS. | | | | | | | | | | 2 | 2 | 2 | | | | | | | | |
| b. DEVISE METHODS FOR CROSSING THE STRUCTURAL ELEMENT TO STRUCTURAL ELEMENT INTERFACE FOR DEPLOYABLE & ERECTABLE STRUCTURES. | | | | | | | | | | 2 | 2 | 2 | | | | | | | | |
| c. CONCEPT DEVELOPMENT OF INTRA-ELEMENT POWER AND SIGNAL DISTRIBUTION FOR ASSEMBLED SPACE SYSTEMS. | | | | | | | | | | 2 | 2 | 2 | | | | | | | | |
| **G.2 POWER DISTRIBUTION FOR LARGE SPACE STRUCTURES** | | | | | | | | | | 2 | | | | | | | | | | |
| **TASKS:** a. DEFINITION OF GENERAL POWER REQUIREMENTS FOR CONCEPTUALLY PLANNED LARGE SPACE STRUCTURES. | | | | | | | | | | 2 | | | | | | | | | | |
| b. CONDUCT TRADE-OFF STUDIES OF DISTRIBUTED POWER SYSTEMS VERSUS A CENTRALIZED DISTRIBUTION SYSTEM | | | | | | | | | | 2 | | | | | | | | | | |
| c. DEVELOP POWER TRANSMISSION METHODS FOR BOTH INTRA AND INTER LARGE SPACE STRUCTURAL ELEMENTS | | | | | | | | | | 2 | | | | | | | | | | |
| **G.3 DATA CHANNEL INTERFERENCE AND MULTIPACTION REDUCTION TECHNIQUES** | | | | | | | | | | | | | 2 | 2 | | | | | | |
| **TASKS:** a. COMPONENT SELECTIONS AND SCREENING | | | | | | | | | | | | | 2 | 2 | | | | | | |
| b. LABORATORY TESTING OVER REQUIRED BANDWIDTHS | | | | | | | | | | | | | 2 | 2 | | | | | | |
| c. RECYCLE OF SURFACE FINISHES AND PROCESSES FOR IMPROVED PERFORMANCE. | | | | | | | | | | | | | 2 | 2 | | | | | | |



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ATLASS PROPOSED TECHNICAL PROGRAM PLAN

| | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV. RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM. | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITHCING/COMM | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM. | ORBITER ASSEMBLY OPERATION/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **H.1 ADVANCED COMPOSITES** | | | | | | | | | | | | | | | | | | 2 | 2 | |
| **TASKS:** | | | | | | | | | | | | | | | | | | | | |
| a. DEVELOPMENT OF LONG-LIFE DIMENSIONALLY STABLE COMPOSITES<br>1. POLYMERIC MATRIX<br>2. METAL MATRIX<br>3. GLASS MATRIX | | | | | | | | | | | | | | | | | | 2 | 2 | |
| b. MANUFACTURING TECHNOLOGY | | | | | | | | | | | | | | | | | | | | |
| c. SPACE CHARGE RELIEF | | | | | | | | | | | | | | | | | | | | |
| d. ELECTRICALLY CONDUCTING STRUCTURAL MATERIALS | | | | | | | | | | | | | | | | | | | | |
| **H.2 ADVANCED THERMAL CONTROL** | 2 | 2 | 2 | 3 | | | | | 3 | | | | | | | | | | | |
| **TASKS:** | | | | | | | | | | | | | | | | | | | | |
| a. INTEGRAL THERMAL CONTROL SURFACE | | | | | | | | | 3 | | | | | | | | | | | |
| b. HEAT PIPE TECHNOLOGY | | | | | | | | | | | | | | | | | | | | |
| c. APPLIED THERMAL CONTROL COATINGS | 2 | 2 | 2 | 3 | | | | 2 | | | | | | | | | | | | |
| d. RADIATOR MATERIALS TECHNOLOGY | | | | | | | | | | | | | | | | | | | | |
| **H.3 ADVANCED METALS** | 2 | 2 | 3 | 2 | | | | 2 | | | | | | | | | | | | |
| **TASKS:** | | | | | | | | | | | | | | | | | | | | |
| a. EVALUATION OF THIN GAUGE STRUCTURAL ALLOYS<br>b. EVALUATION OF LIGHT-WEIGHT STRUCTURAL ALLOYS | 2 | | 2 | 2 | | | | 2 | | | | | | | | | | | | |
| c. CURRENT CONDUCTING ELEMENTS | | | | | | | | | | | | | | | | | | | | |
| d. CONDUCTING SURFACES FOR FABRICS, FILMS, MESHES, COMPOSITES | | 2 | 3 | 2 | | | | | | | | | | | | | | | | |
| e. REFLECTING SURFACES FOR FABRICS, FILMS, MESHES | 1 | 1 | 2 | 1 | | | | | | | | | | | | | | | | |
| f. MANUFACTURING TECHNOLOGY | | | | | | | | | | | | | | | | | | | | |

Table B-3. Technology Requirement/ATLASS Task Matrix (Cont.)

SHEET 10 OF 10

| ATLASS PROPOSED TECHNICAL PROGRAM PLAN | 50-100m ERECTABLE STRUCTURE/COMM. | 20-30m MULTI-BEAM DEPLOYABLE REFLECTOR/RADIOMETER | 100-300m DEPLOYABLE PHASED ARRAY/SURV. RADAR | 50-100m SCANNING DEPLOYABLE REFLECTOR/RADIOMETER | CABLE & LINE DEPLOYMENT/SURV. RADAR | LARGE PLATFORM ATTITUDE CONTROL/COMM | PRECISION ATTITUDE CONTROL/RADIOMETER | 100-600m DEPLOYABLE MAST/SURV. RADAR | FIGURE MEASUREMENT & CONTROL/RADIOMETER | POWER DISTRIBUTION/COMM. | SIGNAL DISTRIBUTION/COMM/RADAR | CENTRAL COMMAND/CONTROL/SWITCHING/COMM | MULTIPACTION/EMI SUPPRESSION/SURV. RADAR | RF PATTERN PREDICTION/SURV. RADAR | ORBITER ASSEMBLY AIDS/COMM | ORBITER ASSEMBLY OPERATION/COMM/RADAR | LOW T/W ORBIT TRANSFER PROP/COMM/RADAR | LONG-LIFE DIMENSIONALLY STABLE/COMM | GROUND TEST & VALIDATION/COMM/RADAR | MODEL & SCALING/RADIOMETER/SURV. RADAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **H.4 SPACE-STABLE POLYMERIC MATERIALS** | | 3 | 2 | 3 | | | | | | | | | 3 | | | | | | | |
| TASKS: | | | | | | | | | | | | | | | | | | | | |
| a. THERMOPLASTIC & THERMOSET STRUCTURAL MATERIALS | | | | 3 | | | | | | | | | | | | | | | | |
| b. RIGIDIZING MATERIALS FOR DEPLOYABLE SYSTEMS | | 3 | | 3 | | | | | | | | | | | | | | | | |
| c. FILMS, FABRICS, MESHES AND CABLES | | 2 | 2 | 2 | | | | | | | | | | | | | | | | |
| d. ADHESIVE SYSTEMS | | | | | | | | | | | | | 3 | | | | | | | |
| e. SPACE CHARGE RELIEF | | | | | | | | | | | | | | | | | | | | |
| f. LONG-TERM OUTGASSING & REDEPOSITION EFFECTS | | | | | | | | | | | | | | | | | | | | |
| g. MANUFACTURING TECHNOLOGY | | | | | | | | | | | | | | | | | | | | |
| **H.5 EVALUATION OF SPACE ENVIRONMENTAL EFFECTS ON MATERIALS** | | | | | | | | | | | | | | | | | | 3 | 3 | |
| TASKS: | | | | | | | | | | | | | | | | | | | | |
| a. ENVIRONMENT DEFINITION & TEST STANDARDIZATION | | | | | | | | | | | | | | | | | | 2 | | |
| b. DEFINITION OF TEST FACILITY REQUIREMENTS* | | | | | | | | | | | | | | | | | | | 2 | |
| c. SHORT-TERM TESTS OF CANDIDATE MATERIALS FOR LEO AND GEO ENVIRONMENTS | | | | | | | | | | | | | | | | | | | 2 | |
| d. DEVELOPMENT OF ACCELERATED LABORATORY TEST METHOBS | | | | | | | | | | | | | | | | | | | 2 | |
| e. DEVELOP MODELS FOR PREDICTING LONG-TERM ENVIRONMENTAL EFFECTS | | | | | | | | | | | | | | | | | | | | |
| f. REAL-TIME & ACCELERATED LONG-TERM LABORATORY TESTS | | | | | | | | | | | | | | | | | | 3 | | 3 |
| g. FLIGHT EXPERIMENT DEFINITIONS | | | | | | | | | | | | | | | | | | | 3 | |
| h. LONG-TERM FLIGHT EXPERIMENT** | | | | | | | | | | | | | | | | | | | 3 | |
| i. CORRELATION OF LONG-TERM FLIGHT & LABORATORY TEST DATA *** | | | | | | | | | | | | | | | | | | 3 | 2 | |
| j. SPACE DEBRIS EFFECTS EVALUATION | | | | | | | | | | | | | | | | | | 2 | | 2 |
| **H.6 JOINING** | | | | | | | | | | | | | | | | | | 2 | | |
| TASKS: | | | | | | | | | | | | | | | | | | | | |
| a. DEFINE JOINING TECHNIQUES | | | | | | | | | | | | | | | | | | 2 | | |
| b. DEVELOPMENT OF SELECTED JOINING TECHNIQUES | | | | | | | | | | | | | | | | | | 2 | | |
| c. EVALUATION OF SELECTED TECHNIQUES | | | | | | | | | | | | | | | | | | 2 | | |

Table B-4. Summary of ATLASS Technology Development for Proposed Mission Scenarios

| ATLASS TECHNOLOGY TASKS | TECH. DEV. REQD |
|---|---|
| B. ANALYSIS & INTEGRATION DESIGN | |
| 1. EM ANALYSIS | 3 |
| 2. CONTROLS ANALYSIS | 4 |
| 3. STRUCTURAL & THERMAL LOADS | 3 |
| 4. STRUCTURAL DYNAMICS | 3 |
| 5. INTEGR. DESIGN DEVELOPMENT | 3 |
| C. STRUCTURAL CONCEPTS, ERECTABLE | |
| 1. CONCEPT DEVELOPMENT | 2 |
| 2. BASIC ELEMENTS | 2 |
| 3. ERECTABLE UNIONS/JOINTS | 2 |
| 4. MULTI-ELEMENT MODULE TESTS | 3 |
| 5. ASSEMBLY TECHNIQUES | 4 |
| 6. MAJOR GROUND TEST | 4 |
| D. STRUCTURAL CONCEPTS, DEPLOYABLE PLATFORM | |
| 1. CONCEPT DEVELOPMENT | 3 |
| 2. TEST FACILITY MODIFICATION | 2 |
| 3. MODULE DEPLOYMENT TESTS | 3 |
| 4. ASSEMBLY OF DEPLOYED MODULES | 3 |

| ATLASS TECHNOLOGY TASKS | TECH. DEV. REQD |
|---|---|
| E. STRUCTURAL CONCEPTS, DEPLOYABLE REFLECTORS | |
| 1. CONCEPT DEVELOPMENT | 3 |
| 2. MODULE DEPLOYMENT TESTS | 3 |
| 3. STRUCTURAL MEASURE SENSOR DESIGN | 2 |
| 4. SURF. ACCURACY SENSITIVITY EVALUATION | 4 |
| F. CONTROL SYSTEMS | |
| 1. SHAPE CONTROL CONCEPTS | 3 |
| 2. ATTITUDE CONTROL CONCEPTS | 4 |
| 3. ORBIT TRANSFER, STATIONKEEPING | 3 |
| 4. CONTROL SYSTEM INTEGRATION | 3 |
| G. ELECTRONICS | |
| 1. SIGNAL CONDITION, DATA ACQUISITION | 2 |
| 2. POWER DISTRIBUTION | 2 |
| 3. EMI, MULTIPACTION EFFECTS | 2 |
| H. MATERIALS TECHNOLOGY FOR LONG LIFE | |
| 1. ADVANCED COMPOSITES | 2 |
| 2. ADVANCED THERMAL CONTROL | 3 |
| 3. ADVANCED METALS | 3 |
| 4. SPACE STABLE POLYMRRS | 3 |
| 5. SPACE ENVIRONMENTAL EFFECTS | 3 |
| 6. JOINING | 2 |

surface accuracy, and on-orbit assembly techniques. A summary matrix, Table B-5, shows the correlation between the composite technology requirements and ATLASS first-level task areas. This matrix also shows the task areas best addressing the technology requirement.

Table B-5. Correlation Between Technology Requirements and ATLASS Tasks

| Composite Technology Requirements | ATLASS Proposed Technology First-Level Tasks | | | | | | | Overall Maximum Technology Develop. |
|---|---|---|---|---|---|---|---|---|
| | B | C | D | E | F | G | H | |
| 50-100 m erectable structure | 2 | 3 | | | | | 2 | 3 |
| 20-30 m multi-beam deploy. reflect. | 2 | | | 3 | | | 3 | 3 |
| 100-300 m deploy. phased array | 3 | | 3 | 2 | | | 3 | 3 |
| 50-100 m scan deploy. reflect. | 3 | | | 3 | 2 | | 3 | 3 |
| Cable and line deployment | 2 | | | | | | | 2 |
| Large platform attitude control | 3 | | | 2 | 3 | | | 3 |
| Precision attitude control | 3 | | | 4 | 3 | | | 4 |
| 100-600 m deployable mast | 3 | | 3 | | | | 2 | 3 |
| Figure measurement and control | 4 | | | 4 | 4 | | 3 | 4 |
| Power distribution | | | | | | 2 | | 2 |
| Signal distribution | | | | | | 2 | | 2 |
| Central command/control switching | | | | | | 2 | | 2 |
| Multi-paction/EMI suppression | | | | | | 2 | 3 | 3 |
| RF pattern prediction | 3 | | | | | 2 | | 3 |
| Orbiter assembly aids | | 3 | | | | | | 3 |
| Orbiter assembly operation | 2 | 4 | 3 | | | | | 4 |
| Low T/W orbit transfer prop. | 2 | 2 | | | 3 | | | 3 |
| Long-life stable composites | | 2 | | | | | 3 | 3 |
| Ground test and validation | | 4 | 3 | 4 | 3 | | 3 | 4 |
| Model and scaling | 3 | 2 | 2 | 4 | 3 | | | 4 |

Each of the technology requirements availability dates has been identified to be consistent with the proposed scenario schedule. A method of assessing technology development trends, based on the approach used in the NASA *Outlook for Space* study, was employed using Rockwell Space Division technology specialists. Two specific questions were addressed to each technology requirement: (1) *Where are we now?* and (2) *What will be?* The results of these "experts" opinion are charted as "Technology Assessments" in the main body of the report. Table B-6 shows the important technology trend availability dates and the percentage of current technology applicable to the specific requirements for the proposed scenario. It can be clearly seen that some technology requirements are predicted to be available in time for the proposed scenario design schedule; other requirements and availability dates are clearly incompatible. For example, Orbiter assembly operations technology will not be available until 1985, while the technology is required by 1981 for both the communication and surveillance radar missions. This early date (1981) is dictated by the importance of assembly operations being resolved before several other technologies can be fully validated. Therefore, some technologies will

Table B-6. Technology Availability and Requirement Dates

| Composite Technology Requirements | Surveillance Radar | Radiometer | Communications | Overall Maximum Technology Development | Year when Technology is Required | Technology Trend Availability Date | Percentage Current Tech. Applicable |
|---|---|---|---|---|---|---|---|
| 50- to 100-m erectable structure | | | X | 3 | 1982 | 1982 | 20 |
| 20- to 30-m multi-beam deployable reflector | | X | | 3 | 1982 | 1980 | 50 |
| 100- to 300-m deployable phased array | X | | | 3 | 1983 | 1987 | 0 |
| 50- to 100-m scanning deployable reflector | | X | | 3 | 1984 | 1983 | 20 |
| Cable and line deployment | X | | | 2 | 1983 | - | - |
| Large platform attitude control | | | X | 3 | 1982 | 1981 | 70 |
| Precision attitude control | | X | | 4 | 1985 | 1983 | 60 |
| 100- to 600-m deployable mast | X | | | 3 | 1983 | 1983 | 10 |
| Figure measurement and control | | X | | 4 | 1984 | 1987 | 20 |
| Power distribution | | | X | 2 | 1985 | 1984 | 30 |
| Signal distribution | X | | X | 2 | 1985 | 1981 | 30 |
| Central command/control switching | | | X | 2 | 1985 | 1981 | 40 |
| Multi-paction/EMI suppression | X | | | 3 | 1983 | 1981 | 50 |
| RF pattern prediction | X | | | 3 | 1985 | 1981 | 50 |
| Orbiter assembly aids | | | X | 3 | 1982 | 1980 | 20 |
| Orbiter assembly operation | X | | X | 4 | 1981 | 1984 | 10 |
| Low T/W orbit transfer prop. | X | | X | 3 | 1983 | 1980 | 80 |
| Long-life stable composites | | | X | 3 | 1983 | 1982 | 20 |
| Ground test and validation | X | | X | 4 | 1981 | 1980 | 30 |
| Model and scaling | X | | | 4 | 1980 | 1981 | 10 |

require special concentrated emphasis to shorten their development schedules. While many of the Orbiter assembly operations can be developed with ground-based simulated space environments, there are certain important aspects of assembly operations that are only adequately validated with actual flight experiments. Since these experiments will be conducted on board the early Shuttle missions, and these flights do not start before the early 1980's, it will impose certain restrictions on realistically shortening the technology development schedule.

# APPENDIX C

## TECHNOLOGY DEVELOPMENT PRIORITY RATING DISCUSSION

The priority methodology and a technology priority summary for the 20 technology areas of the current study were discussed on pages 46 through 49 of this report. The summary charts are repeated below as Tables C-1 and C-2.

Table C-1. Priority Rating Methodology

| Priority Category | Question 1<br>*Are there viable alternatives if the need is unsatisfied?* | Question 2<br>*Could the required need date be satisfied by the on-going technology rate/trend line?* |
|---|---|---|
| 1. Highest | NO | NO |
| 2. Next highest | NO | YES |
| 3. Next highest | YES | NO |
| 4. Lowest | YES | YES |

Table C-2. Technology Priority Summary

| | |
|---|---|
| PRIORITY 1 | • 100- to 300-m deployable phased array structure<br>• Orbiter assembly operations<br>• Figure measurement and control<br>• Modeling and scaling laws |
| PRIORITY 2 | • 50- to 100-m erectable structures<br>• 20- to 30-m multibeam deployable reflector structure<br>• Large platform attitude control system<br>• Attitude control system for flexible structures<br>• RF pattern prediction, phased array<br>• Power distribution |
| PRIORITY 3 | • Long-life dimensionally stable composites<br>• 100- to 600-m deployable masts<br>• Long-life polymer film |
| PRIORITY 4 | • 50- to 100-m deployable reflector structure<br>• Orbiter assembly aids<br>• Low-thrust propulsion<br>• Ground test and validation facility requirements<br>• Signal distribution<br>• Centralized command/control switching<br>• Multi-paction/EMI suppression |

This appendix describes briefly the rationale that entered into the answers to the methodology questions and the resulting priority rating for each of the technology requirements analyzed. The referenced report pages provide the applicable general discussion of the priority methodology.

The intended meaning for the priority ratings as established in the current study is to point out to the planners of large area space structures and missions those technology areas which first need attention and further planning studies if the assumed mission scenario is to be accomplished. If other types of large area space structure missions become predominant in a future scenario, the list of technology requirements and the resulting priority determinations could be markedly different.

50- TO 100-m ERECTABLE STRUCTURES

Because of the size and mission equipment loading for the proposed structures, the erectable structure approach appeared to be the only viable approach. The present interest and current studies of large space structures indicate that the selection of appropriate structural configurations and materials can be accomplished by the required 1982 date. The NO and YES answers to the ranking methodology questions result in a No. 2 priority ranking.

20- TO 30-m MULTI-BEAM DEPLOYABLE REFLECTOR STRUCTURES

Because of the Orbiter dimensional limits, the six 23-m parabolic antennas required for the communications application need to be of deployable or erectable design. The current technology in deployable antennas is advanced to the point that erectables in the indicated size range do not appear to be a viable alternative. The analysis results in a NO and YES response to the ranking methodology questions and a No. 2 priority ranking.

100- TO 300-m DEPLOYABLE PHASED ARRAY STRUCTURES

The 180-m phased array application being considered in the present analysis is a unique design with no known viable alternative design concepts. Because the presently conceived design complexities of the lightweight structure and its packaging and handling problems have received only preliminary analyses, it is believed that the current rate of progress cannot achieve the required technology development level by the desired 1983 date. The double NO answers to rating methodology questions result in a No. 1 priority ranking.

50- TO 100-m SCANNING DEPLOYABLE REFLECTOR STRUCTURES

The 50-m scanning deployable reflector application of the scenario utilizes a spherical reflector with a movable feed to provide target scanning without rotation of the entire structural assembly. An alternative to this technique is a phased array design with electronic scanning or the use of multiple smaller antennas. The scanning deployable reflector technology is believed capable of advancing to the required level by the desired 1984 time period. The double YES answers result in a No. 4 priority ranking.

LARGE PLATFORM ATTITUDE CONTROL SYSTEM

The communications satellite provides an example of large platform attitude control requirements. Even with individual pointing controls for each antenna, the platform would still require fairly close stabilization for the multiple antenna payload, and therefore no alternative to the ACS requirement

exists. The control technology for satellites is presently well developed and modifications for the proposed satellite can be achieved in 1982. Therefore, a No. 2 priority ranking (NO, YES) is given for this application.

ACS FOR FLEXIBLE STRUCTURES

Attitude control is an important function that cannot be eliminated from the radiometer application. The proposed mechanical feed scan (rotating feed and variable orientation of feed support) provides extra complexity to the ACS when attached to the relatively flexible antenna support structure. However, with the technology need date of 1985, it is estimated that present technology progress will enable the need to be met; the priority ranking assigned is then No. 2 (NO, YES).

RF PATTERN PREDICTION, PHASED ARRAY

The generation of RF pattern predictions for the phased array surveillance radar application is a necessary requirement for determining the effectiveness of the system. Although the proposed application has some unique features, prediction technology is presently well developed and the requirement date of 1985 should be easily met for this technology area; the priority ranking of No. 2 (NO, YES) is therefore assigned.

ORBITER ASSEMBLY AIDS

Orbiter assembly aids technology was estimated as a requirement for 1982 for some of the earlier flown communications satellite applications. The structure assembly aids presently envisioned consist primarily of the Orbiter RMS units and other relatively simple jigs and fixtures for structural component handling and assembly. It is believed that several alternatives to the present concept exist. Therefore, it is believed that present technology development progress will allow providing required assembly aid concepts in time. The priority ranking assigned is No. 4 (YES, YES).

ORBITER ASSEMBLY OPERATIONS

Orbiter assembly operations technology is required by 1981 in order to have a firm foundation for proceeding with design details of the early communication application large space structures. The assembly operations include not only the operations utilizing the Orbiter assembly aids of the previous chart, but also the maneuvering (or walking) of the Orbiter relative to the structure as the LSS assembly progresses. The rendezvous and docking with the partially assembled structure for the multiple Orbiter missions also require operational analysis. The final proof testing of some of the required techniques requires testing in the space zero-g environment. The presently envisioned programs for such testing may not allow accomplishment until well beyond the 1981 time period. The priority ranking assigned to this technology is, therefore, No. 1 (NO, NO).

LOW-THRUST ORBIT TRANSFER PROPULSION

The low-thrust orbit transfer propulsion technology is required for the communications and radar applications by 1983. The development of solar electric propulsion technology provides a viable alternative to chemical propulsion for these applications. However, the selection of chemical propulsion components for the task provides a well developed technology base which can be ready well before the required date; the priority ranking is the No. 4 (YES, YES).

GROUND TEST AND VALIDATION FACILITIES

For the early communication satellite applications, ground test facilities and validation technology should be available by 1981 in order to be able to proceed with the system and subsystem ground testing program deemed necessary for each of the LSS missions of the scenario. Flight testing could provide a potential alternative to the ground test program for some of the unique requirements of the testing program. The unique tests required are primarily those relating to the provision of zero-g and orbital temperature and vacuum environments for testing of operational assembly techniques, as well as the more conventional materials and component testing. New ground test methodology must be developed in order to be prepared for the development cycles of the various scenario applications. It is estimated that the current level of LSS investigations will allow the required technology level to be ready by the 1981 need date. The priority ranking is therefore No. 4, with the two YES answers to the priority rating methodology questions.

LONG-LIFE DIMENSIONALLY STABLE COMPOSITES

The radar system structure represents a satellite structure for which advanced long-life dimensionally stable composite materials are desired in order to meet structural mass and thermal stability goals. For the size structures considered in the present scenario, there will be alternative, more conventional, materials which can be utilized for the proposed designs. The technology need date for the composite material is determined as 1983. Because of the requirement for some testing in the actual space environment in facilities such as the Long-Duration Exposure Facility (LDEF), it is estimated that the desired level of technology development for the long-life composites may not be achieved until somewhat later than 1983; the priority ranking for this technology is then No. 3 (YES, NO).

100- TO 600-m DEPLOYABLE MAST

The radar application satellite design concept specifies a tripod mast for holding the RF feed module and other subsystems. Each leg of the tripod is approximately 450 m long. This dimension appears to be beyond the present state of the art for packaged canisters of a size compatible with Orbiter delivery. Alternatives to the one-piece deployable mast are available with, for example, the use of on-orbit assembly of structural subassemblies. It is estimated that the development of a deployable mast for the scenario requirement would require somewhat longer than the 1983 need date. The resulting priority ranking for the technology is, then, No. 3 (YES, NO).

FIGURE MEASUREMENT AND CONTROL

The radiometer satellite represents an application where on-orbit sensor figure measurement and control become an important technology in order to assure the most effective mission results. The wide range of radiometer frequencies to be measured and small earth surface target areas require both accurate beam pointing and extremely accurate antenna shape control for the higher frequencies (e.g., 120 GHz). For this desired application, there would be no substitute for on-orbit adjustment of the large 50-m-diameter antenna which requires on-orbit assembly; therefore, accurate figure measurement technology is required. Because of the thermal and other distortions inherent in the 55-degree inclination, 740-km altitude, orbit it is believed that active figure control also will be required. The on-orbit technology for figure measurement and control is being studied, but at the current rate of progress it is estimated that the required level of technology for the above discussed application cannot be achieved until well beyond the 1984 time period. The resulting priority ranking for this technology area is, therefore, No. 1, with the NO, NO answers to the ranking methodology questions.

POWER DISTRIBUTION

The communications satellite represents an application where integrated power distribution from the power source (solar panels) to several scattered user equipments (antennas) is a requirement. Any alternatives would be primarily distribution design details (e.g., voltage selections, etc.) so no basic differences are considered available. The power use technology for space systems is fairly well developed for smaller space systems, and extrapolations to the systems of the present scenario requirements can be accomplished prior to the 1985 need date. The priority ranking for this technology is, then, No. 2 (NO, YES).

SIGNAL DISTRIBUTION

The communication satellite again serves as a model for estimating requirements for the handling of integrated signal distribution for a large space system. Several methods of spacecraft control signal and data transfer can be used. Direct wire, fiber optics, and RF can be alternatives--depending on data volume and distance. It is believed the technology is well studied and that the required development will be accomplished well before the 1985 need date. The priority ranking is, then, No. 4 (YES, YES).

CENTRALIZED COMMAND/CONTROL/SWITCHING

The centralized command/control/switching technology is required by 1985 for application to the potentially complex applications of high data rate, multiple antenna satellites such as the proposed electronic mail missions. Various forms of decentralized on-orbit controls or ground-assisted controls provide alternatives. A great deal of present ground communications RF control developments will be pertinent to the space applications. The required technology level should be available well before the 1985 need date; the priority ranking then is No. 4 (YES, YES).

MULTI-PACTION/EMI SUPPRESSION

The general electronically troublesome areas in space applications represented by multi-paction and EMI suppression must be understood by 1983 in order to proceed with system final designs. There are several design approaches available to deal with these problems for specific applications. Current rate of progress in this technology area is relatively advanced, and it is estimated that the required technology level will be achieved comfortably ahead of the need date. This results in a two-YES response to the priority methodology questions and a No. 4 rating.

LONG-LIFE POLYMER FILMS

The practicability of the current concept for the radar satellite application depends heavily on the availability of durable, yet extremely thin, polymer films. The technology for production and handling needs to be understood by 1983. There would be no viable alternatives for this application. Long-duration testing of candidate materials must be accomplished in the simulated or actual operational environment before this technology can be considered ready. It is estimated that this cannot be satisfactorily done prior to the need date; the priority rating then becomes No. 1 (NO, NO).

MODELING AND SCALING LAWS

The modeling and scaling law methodology needs to be understood early in the LSS program (1980) in order that the predictive techniques may be applied to the many individual and interactive technology areas. There can be no short-circuiting of the requirements to understand these relationships for the large space structure applications being proposed. Because many unique component and module testing requirements result from the LSS designs, it is not estimated that current technology development effort can achieve the desired level in the required time period. The technology area, therefore, receives a priority rating of No. 1 from the two negative responses to the priority methodology questions.